PLOUGHING DEPTH AND WEED CONTROL TREATMENT EFFECTS ON MAIZE PERFORMANCE AND SOIL PROPERTIES

by

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DECLARATION

I hereby declare that this submission is my own work towards the Master of Philosophy in Agricultural Machinery Engineering and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgment has been made in the text.

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ABSTRACT

A field experiment was conducted to determine the effects of ploughing depth and weed control treatments on *obaatanpa* maize (*Zea mays*, L.) performance and soil properties during the 2009 major crop growing season in Kumasi, Ghana. The disc–ploughing depth treatments consisted of 0cm (No–tillage), 10–15cm, 15–20cm and 20–25cm. The weed control treatments included weed control with a hand hoe, cutlass, weed wiper, knapsack sprayer, and no weed control. The experiment was a factorial arranged in a randomised complete block design replicated three times. Overall, the highest seedling emergence was obtained from the 20–25cm ploughing depth plots while the lowest seedling emergence was found in the No–tillage plots. Ploughing depth treatments significantly influenced maize growth and dry matter yield. Ten weeks after planting, ploughing at the 20–25cm depth produced the biggest stem girth (57.53mm), longest root length (46.34cm) and highest dry matter yield (8155kg ha^{-1}). The tallest plant height (180.50cm) and the highest number of leaves (17.71) were recorded in the 15–20cm and the 10–15cm ploughing depth plots respectively. The No–tillage treatment gave the shortest plant height (104.98cm), smallest stem girth (36.49mm), lowest number of leaves (14.87), and lowest dry matter yield (2573kg ha^{-1}). In general, plant height, stem girth, and number of leaves between the 10–15cm, 15–20cm and 20–25cm ploughing depth treatments were statistically similar. Generally, weed control did not have statistical significant effect on maize performance and soil properties. There were no significant interaction effects of ploughing depth and weed control treatments on maize performance and soil properties. There is the need to determine the long–term effects of ploughing depth and weed control treatments on maize performance and soil properties.

DEDICATION

I affectionately dedicate this thesis to my wife, Mary and son, Joel, who I left behind when he was about six months old for their patience and forbearance during the course of my two year absence.

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1. INTRODUCTION

1.1 Background to the Study

Maize (*Zea mays*, L.) is the most important cereal crop in sub-Saharan Africa and, with rice and wheat, one of the three most important cereal crops in the world. Maize is high yielding, easy to process, readily digested, and cheaper than other cereals. It is also a versatile crop; growing across a range of agro-ecological zones (IITA, 2009). Fresh maize on the cob, roasted or boiled is very popular among people of all ages. Furthermore, the position of maize in livestock or poultry feed production cannot be over emphasized (Akobundu, 1987).

In Ghana, maize is the most important cereal crop and has been cultivated in the country for several hundred years. The crop is grown by the vast majority of resource poor rural households in all parts of the country except for the Sudan savannah zone (Morris *et al.*, 1999). The production of maize in Ghana has been increasing since 1965 (FAO Statistical Databases, 2008; Morris *et al.*, 1999 cited by Aikins *et al.*, 2010). However, maize yields in Ghana are generally low (FAO Statistical Databases, 2009). Some of the constraints affecting maize production in Ghana are heavy dependence on rainfall which is erratic, limited use of nitrogenous fertilisers, declining soil fertility, incidence of pests and diseases, and inappropriate tillage practices.

Ploughing is one of the fundamental operations undertaken in conventional tillage. Conventional tillage practices modify soil structure by changing its physical properties such as soil bulk density, soil penetration resistance, soil moisture content (Rashidi and Keshavarzpour, 2007), soil porosity and soil air. Papworth (2010) indicated that tillage influences crop growth and yields by changing soil structure and moisture removal patterns over the growing season. In Ghana, disc ploughing is undertaken in many farming areas including Ejura, Afram Plains, Atebubu, Nkoranza, Techiman, Wenchi, Nyankpala and Tamale (Aikins *et al*., 2007). Many of the tractor operators plough without knowing the depth at which they plough, and the effect of the depth of ploughing on the performance of the crop as well as on the soil physical properties.

Increasing ploughing depth may be beneficial because of its loosening effect, but it increases the draught requirement and ploughing cost (Arvidsson, 1998). Deep tillage has increased the yield of numerous crops (Barbosa *et al*., 1989; Mathers *et al*., 1971 cited by Wesley *et al*., 2001) and has proven to be a practical method of increasing soil water intake rates (Wesley *et al*., 2001). Increasing tillage depth results in reduced amounts of residue present on the soil surface (Raper, 2002). Data is lacking on the optimum ploughing depth for the production of maize in Ghana.

The use of conservation tillage can play an important role in reducing soil erosion and improving soil quality (Uri *et al*., 1999) and can be an attractive alternative to conventional tillage for farmers because of its potential to minimize labour and fuel consumption and to lower total production cost (Uri, 2000). No tillage is a system where crops are grown in narrow slots or tilled strips in previously undisturbed soil (Aikins, 2009). No tillage means less soil compaction, lower fuel and labour costs. Additionally, No tillage has many other advantages such as controlling wind and water erosion, reducing soil moisture loss and greenhouse gas (carbon) emissions (Lindstrom and Reicosky, 1997 cited by Chen *et al*., 2005). Rydberg (1987) indicated that ploughless tillage may improve the soil structure compared with mouldboard ploughed soil, for example by increasing the organic matter content close to the soil surface. There are also negative effects such as increased mechanical resistance hampering root growth (Comia *et al*., 1994; Rydberg, 1987 cited by Arvidsson, 1998).

The use of zero or reduced tillage has been shown to be financially advantageous, beneficial for soil aggregation and helpful in reducing soil erosion, as well as conserving soil moisture and increasing soil organic matter across a range of soil types, cropping systems and climates (Grandy *et al*., 2006; Vullioud *et al*., 2006; Machado *et al*., 2007; Cantero-Martinez *et al*., 2007 cited by Šíp *et al*., 2009).

Apart from lack of information on optimum depth of ploughing, another constraint affecting maize production in Ghana is poor weed control. Weeds compete with crop plants for water, nutrients, space and light and also give refuge to pests and diseases (Abu-Hamdeh, 2003); interfere with crops by releasing certain allelochemicals in the rhizosphere and ultimatly decrease crop yield (Rice, 1984; Mahmood *et al*., 2009). Weed control is often the most important agricultural task facing farmers in developing countries. Manual weeding can be very demanding of labour. Tewari *et al*., (1993) quoted figures of 300–1200 hours per hectare for India. Sims *et al*., (1987) cited by Sims (2000) reported that Mexican smallholder farmers, using both human and animal power, devoted about a quarter of their labour input to weeding. In both cases weeding took place during peak labour demand seasons, and could be the factor limiting the area cultivated by farm families (Sims, 2000). Depending on the amount of weeds, 50 to 300 hours per hectare is used for manual weeding in carrots and onions (Ørum and Christensen, 2001 cited by Sørensen and Jørgensen, 2005).

Weed control in maize in Ghana is carried out using hand hoes, cutlasses (Adjei *et al*., 2003; Tweneboah, 2000), and by hand pulling. The effect is high labour requirements and often late and incomplete weed control resulting in considerable crop yield losses. Herbicide application using knapsack sprayers in maize production in Ghana is also increasing. The weed wiper is a weed control tool that could be potentially used to control weeds in maize. Kwami-Adala (2008) reported high maize growth and dry matter yield using the weed wiper in comparison with other weed control tools. However, more information is required on controlling weeds with the weed wiper in comparison with other weed control tools on the performance of maize in Ghana.

1.2 Significance of the Study

Ploughing depth may affect crop production costs. Deep tillage requires substantial expenditure of energy and entails significant cost to producers (Wells *et al*., 2005). On the other hand, no tillage may influence crop growth and yield positively or negatively. Ploughing depth may also affect weed growth and crop performance. In Ghana, weed control in maize production is carried out using hand hoes, cutlasses, or hand pulling. The seasonality of rainfed field crop cultivation imposes a serious bottleneck in terms of time and amount of weeding, particularly where weeding is commonly dependent on manual labour (Norman *et al*., 1981). Delay and negligence in weeding operation affect crop yield (Yadav and Pund, 2007). However, little research has been reported in Ghana on ploughing depth and weed control treatment effects on crop performance and soil properties.

1.3 Aim and Objectives of the Study

The main aim of the study was to compare the effects of ploughing depth and weed control treatments on *obaatanpa* maize variety performance and soil properties. The specific objectives of the study were to:

1. determine the effect of ploughing depth and weed control treatments on seedling emergence, plant height, stem girth, number of leaves, root length, and dry matter yield of *obaatanpa* maize variety
2. determine the effect of ploughing depth and weed control treatments on soil penetration resistance, dry bulk density, moisture content, total porosity and air content and
3. determine the effect of ploughing depth on weed dry matter yield

2. LITERATURE REVIEW

2.1 MAIZE

Maize (*Zea mays* L.), is an annual monocotyledon belonging to the Poaceae family and the Maydeae tribe of which eight different genera have been recognised by taxonomists (Raemaekers, 2001). The origin of maize is still controversial. At present there are two views that maize originated from: the wild grass teosante or – an extinct form of pop corn (Sallah and Twumasi-Afriyie, 1994). According to Yayock *et al*. (1988) maize originated in tropical America, but is now one of the world's most cultivated food crops. It has a remarkably adaptable physiology and is highly described as both a tropical and temperate crop. However, being a crop of tropical origin, it thrives best in warm to hot climates. It can be successfully grown as a rain fed crop and under irrigation. It is mainly grown for the grain, but is also grown for fodder, silage and as sweet corn eaten on the cob as a vegetable.

Maize is one of the most important cereal crops in the countries of West and Central Africa. Its role in human diet, animal feed and industries increased tremendously in the later part of the 20th Century. Maize has a relatively short growth cycle, is easy to grow solely or in a mixture with other crops, and its preparation as food is relatively easy (Badu-Apraku *et al.*, 2004).

2.1.1 The physiology of maize

The maize stems look like bamboo cane and the joints (nodes) are about 40–50 cm apart. The stems are erect and the height varies from 1–3 m. Maize has a very distinct growth form, the lower leaves being like broad flags, 50–100 cm long and 5–10 cm wide. The leaves consist of a leave sheath which grasps the stem and a long slender tapering leaf blade and a ligule. The ligule marks the point where the leaf blade extends from the stem. A leaf occurs at each node. The leaves are opposite ranked. A mature maize plant produces 20-23 leaves depending on its period of maturity and development (Twumasi-Afriyie and Sallah, 1994). The leaf is supported by a prominent mid-rib along its entire length.

Under the leaves and close to the stem grow the ears. They are female inflorescences, tightly covered over by several layers of leaves, and so closed in by them to the stem, that they do not show themselves easily until the emergence of the pale yellow silks from the leaf whorl at the end of the ear. The silks are elongated stigmas that look like tufts of hair, at first green, and later red or yellow.

The apex of the stem ends in a male flower, the tassel. For each silk on which pollen from the tassel lands, one kernel of maize is produced. As the plant matures the cob becomes tougher and the silk dries to inedibility. The kernels dry out and become difficult to chew without cooking them tender first in boiling water. The grains are about the size of peas, and adhere in regular rows round a white pithy substance, which forms the ear.

The root system is fibrous, spreading in all directions. The primary roots develop from the seed at germination and supply most nutrition during the first weeks. The permanent or coronal roots arise from the crown just below the soil surface once the seedling is growing well. Later on, more adventitious roots develop from above ground nodes and grow into the soil, their function being to anchor the plant and support it in upright position (Raemaekers, 2001).

2.1.2 Importance of maize

In sub-Saharan Africa, maize is a staple food for an estimated 50% of the population and provides 50% of the basic calories (Ofori and Kyei-Baffour 2006). Maize contains 1.2 to 5.7 % edible oil. Varieties developed particularly for oil production contain as much as 14% (Dr. Corn, 2008). Maize flour is used as a thickening agent in the preparation of many edibles like soups, sauces and custard powder. Maize syrup is used as an agent in confectionary units. Maize sugar (dextrose) is used in pharmaceutical formulations as sweetening agent in soft drinks, etc. Corn gel on account of its moisture retention character is used as a bonding agent for ice-cream cones, and as a dry dusting agent for baking products.

Above all, maize is easier to process, readily digested and cheaper than other cereals. It is also a versatile crop, growing across a range of agro-ecological zones and adapts well to different types of soil. It grows on deep, fine structured, well aerated, well drained soils that are rich in organic matter and has a high yield capacity. With good cultural practices and fertiliser application, maize gives good yield.

2.1.3 Uses of maize

Maize (*Zea mays* L.) has a multitude of uses and ranks second to wheat among the world's cereal crops in terms of total production. Also, because of its worldwide distribution and lower prices relative to other cereals, maize has a wider range of uses than any other cereal. It is the staple food crop and mainstay of rural diets, as well as a cash crop. In poor communities it is the main source of calories and protein, as well as the primary weaning food for babies (Mashingaidze, 2004). In developed countries, maize is consumed mainly as second-cycle produce, in the form of meat, eggs and dairy products. In developing countries, maize is consumed directly and serves as staple diet for so many people. Africans consume maize as a starchy base in a wide variety of porridges, pastes, grits and beer. Green maize (fresh on the cob) is eaten parched, baked, roasted or boiled and plays an important role in filling the hunger gap after the dry season (Ofori and Kyei-Baffour, 2006). Each country has one or more maize dishes that are unique to its culture. Examples are *Ogi* (Nigeria), *Kenkey* (Ghana), *Koga* (Cameroon), *Tô* (Mali), *Injera* (Ethiopia), *Ugali* (Kenya). Most of these products are still traditionally processed (Okoruwa, 1997). Every part of the maize plant has economic value - the grain, leaves, stalk, tassel and cob can all be used to produce a large variety of food and non-food products (Raemaekers, 2001).

2.1.4 Maize cultivation

Successful maize production depends on the correct application of production inputs that will sustain the environment as well as agricultural production. These inputs are adapted cultivars, plant population, soil tillage, fertilisation, weed, insect and disease control and harvesting.

2.1.5 Climatic requirements

Maize tolerates a wide range of environmental conditions, but grows well in warm sunny climates with adequate moisture (Purseglove, 1992). The crop is grown in climates ranging from temperate to tropic during the period when mean daily temperatures are above 15°C. Although the minimum temperature for germination is 10 ºC, germination will be faster and less variable at soil temperatures of 16 to 18 ºC. At 20 ºC, maize should emerge within five to six days. The critical temperature detrimentally affecting yield is approximately 32 ºC (du Plessis, 2003).

2.1.6 Water requirements

Maize is an efficient user of water in terms of total dry matter production and among cereals it is potentially the highest yielding grain crop. For maximum production a medium maturity grain crop requires between 500 and 800 mm of water depending on climate. Maize demands maximum moisture during tasselling and silking periods. Favourable water conditions for maize exist when soil moisture is surplus at the roots and total rainfall of at least 400 mm is favourably distributed during the growing season. The most favourable soil-moisture content for the growth and development of maize and for high yield is 60-70% of field capacity. In drought conditions, the rate of growth decreases, the silking period is retarded and grain filling and formation is significantly reduced resulting in yield reduction (Raemaekers, 2001).

2.1.7 Soil requirements

The most suitable soil for maize is one with a good effective depth, favourable morphological properties, good internal drainage, an optimal moisture regime, sufficient and balanced quantities of plant nutrients and chemical properties that are favourable specifically for maize production (du Plessis, 2003). While maize is adapted to a wide variety of soils in the tropics, ranging from sand to heavy clays, most maize is grown on well structured soils of intermediate texture (sandy loam to clay loams), which provide adequate soil water, aeration and penetrability. In the tropics as a whole Oxisols, Ultisols, Alfisols and Inceptisols have the greatest potential for maize production. Vertisols and Mollisols are excellent cereal soils but are limited in extent in the tropics (Norman *et al.*, 1995). Maize does well on most soils but less so on very heavy dense clay and very sandy soils. The soil should preferably be well-aerated and well-drained as the crop is susceptible to waterlogging. The fertility demands for grain maize are relatively high and amount, for high-producing varieties, up to about 200 kg/ha N, 50 to 80 kg/ha P and 60 to 100 kg/ha K. In general the crop can be grown continuously as long as soil fertility is maintained.

2.1.8 Land preparation

The primary purposes of land preparation prior to planting are to create a soil structure favourable for crop growth, to incorporate residues, and to control weeds and diseases. In areas where the soil structure is adequate to allow good growth without cultivation, weeds are controlled by other methods like the use of herbicides. On the other hand, the land may be scraped off the weeds and stubble of previous crop and ploughed.

On subsistence farms the land preparation begins before the commencement of rain to take full advantage of it although the operation is rarely completed on time, as the dry soil is difficult to work by hand. The common tools used are cutlasses and hoes. On commercial farms, the land is prepared by tractor drawn implements. An early ploughing before the onset of the rain is followed by one or two harrowing. As at now this practice is changing because of the high cost of operating machinery and the difficulty to obtain spare parts to experiment with reduced-tillage and zero tillage (Raemaekers, 2001)

2.1.9 Sowing depth

The correct depth of planting is deep enough to allow seed to take up water, to protect it from desiccation or birds, and to prevent it from germinating with light rains, but shallow enough to allow the seedling to reach the surface before depleting its food reserves or being attacked by soil insects or diseases. However, sowing depth of maize varies from 5 to 10 cm, depending on the soil type and sowing date (du Plessis, 2003). If seeds are sown at different depths, there will be an uneven germination that will result in uneven crop stand, which in turn, affect crop production activities like harvesting. Crop will also mature unevenly and will therefore, pose a problem for mechanical harvesting. Depth of seed placement is influenced by factors such as seed size, type of seedling emergence, soil type and soil moisture (Acquaah, 2001).

2.1.10 Sowing

A good sowing is one that allows seed to be placed at the correct depth and provides good contact between seed and soil. Firming the soil around the seed at planting assist the seed to imbibe water from the soil. Seeds with loosely packed soil around it may suffer desiccation in a moisture stress and die if the germination process has started. Prior to emergence the seed depends on stored food reserves (Twumasi-Afriyie and Sallah, 1994). Sowing can be accomplished by machine or manual labour. In the normal case, seeds are dropped by hand behind the plough or using a cutlass, hoe or dibbled into the soil. Whatever method of sowing is adopted the objective of obtaining the desired plant population should be achieved.

2.1.11 Spacing

Seeds are usually sown at a varied variety of spacing within and between rows depending on cultivar type, plant nutrient, previous crop and expected rainfall or moisture regime. The population can vary between 15,000 and 90,000 plants/ha (Gibbon and Pain, 1991). The best way to get uniform plant stands is to plant in regularly spaced rows and at regular intervals within the row. Maize is usually planted in rows from 60– 90 cm apart. Plant spacing or plant density plays an important role in the competitive balance between weeds and maize (Abouziena, *et al.*, 2007). Singh and Singh (2006) stated that the weed density and other measures of weed abundance usually decrease as crop density increase. They added that narrow row spacing affect the weeds and increase crop yield.

2.1.12 Weed control

The methods employed to manage weeds vary, depending on the situation, available research information, tools, economics, and experience (Monaco, 2002). Weed control is an important management practice for maize production that should be carried out to ensure optimum grain and forage yield. Weed control in maize can be carried out by mechanical and/or chemical methods. Weeds between plant rows are removed generally by mechanical cultivation, while weeds on the rows are controlled by hand hoeing or by herbicides. Good weed control usually involves a combination of the available methods plus timeliness and good cultural practices (Abu-Hamdeh, 2003). According to James *et al*. (2000) and Doğan (2003), the best time to minimise the effect of weeds on maize yield is within 4-8 weeks after planting when maize is in the 2-8 leaf stage.

2.1.13 Fertiliser Application

Fertilizer application is one major farming operation needed to correct deficiencies in the soil in order to ensure proper growth and functioning of crops with the aim of increasing yield (Srivastava *et al*., 2006; Webster and Wilson, 1992 cited by Aikins *et al*., 2010).

Maize is particularly sensitive to soil nutrient deficiencies of both the major and minor nutrients. Amounts and types of fertiliser required will depend on soil type, cropping history and geographical location (Price, 1997). Maize requires adequate supply of nutrients particularly nitrogen, phosphorus and potassium for good growth and high yield. Nitrogen and phosphorus are very essential for good vegetative growth and grain development in maize production. The quantity required of these nutrients particularly nitrogen depends on the pre-clearing vegetation, organic matter content, tillage method and light intensity (Kang, (1981) cited by Onasanya *et al.*, 2009). In general, the fertiliser requirements of maize in tropical conditions are about 100-120 kg N, 40 kg P and 50 kg K per hectare (Yayock *et al.* 1988). Fertilizer is normally placed 5 cm below the depth of the seed and about 5 cm to the side at the time of planting (Katinila *et al.*, 1998). This is accomplished by digging a single hole beside each seed, placing fertilizer in the hole, and covering it with soil. Alternatively, a continuous furrow is made along the length of the planting row. Fertilizer is placed in the furrow and covered with soil. The seed is planted on top of this soil and covered properly.

2.1.14 Harvesting and storage

Most maize is harvested by hand. This often involves large numbers of workers and associated social events. Some one-and two-row mechanical pickers are used. By hand or mechanical picker, the entire ear is harvested which then requires a separate operation of a maize sheller to remove the kernels from the ear. The combine with a maize head cuts the stalk near the base and then separates the ear of maize from the stalk so that only the ear and husk enter the machinery. The combine separates the husk and the cob, keeping only the kernels.

The time of harvesting is obviously dictated by the time of planting, but in general maize require up to 120 days to reach maturity. The early maturity varieties can go up to between 75-80 days. Immediately the grain is dry maize should be harvested, mostly at a moisture content of 15-20%. The fresh maize is best harvested as soon as the stigmas dry out or turn brown (Yayock *et al*., 1988). Generally, it is necessary that the harvest should coincide with the dry periods to avoid the danger of grain rotting, growth of mould, or germination on the cob. Harvested maize is usually left out for further drying.

Maize to be stored should not contain more than 13% moisture, and farmers are advised to store maize on open cribs or in sacks. Cribs should not be wider than one metre, and a depth of 60–100 cm is considered good for storage on drier cribs. The narrow width helps maize to dry more quickly. This means of storing maize while it dries helps protect maize from mould. When the maize is dry enough, it may be shelled and the grain can be stored in sacks or bins (Katinila *et al.*,1998).

2.1.15 Pests and diseases control

The most prominent field pests in maize are stalk borers and armyworms. Damages caused by stalk borers are hard to see at first, and by the time a severe attack is noticed, many plants may already have been killed and many others damaged beyond recovery. The stalk borers have a global distribution, and the economic losses caused may be very great or severe. Infected plants have spotted, speckled or white leaves, retarded shoot growth, stunted plant and gradual death (Fröhlich, 1970). For effective control of the stalk borers, several insecticides can be used e.g. Endosulfan. Effective cultural control measures should also be encouraged, including early planting, the use of resistant varieties and the burning of stalks after harvest.

Several species of grasshoppers feed on the foliage of the maize plant. When grasshoppers are abundant, they devour large plants, leaving only the bare stalks or, sometimes, only stubs in the field. Grasshoppers can be controlled with insecticide, preferably applied to the hatching areas when the nymphs are young (Martin *et al*., 2006).

Birds, animals (monkeys), and insects often damage the husks, and the pathogens enter the cobs as secondary infections. Birds and animals can be controlled by scaring, trapping or use of scarecrows. These can be human like figures, shiny objects or bright colours that scare animals away from the field. Insects can be sprayed. If the maize lodges, the pathogens may be transmitted from the soil. All diseased cobs should be destroyed at harvest. Diseased plants and husks should be burned to prevent the pathogens from being carried over to the next year's crop.

The common diseases of maize include smuts, rust, bacterial blight, and streak. These diseases can be controlled by the use of chemicals, seed selection, crop rotation, use of resistance varieties and the removal of alternative host.

To minimize yield reduction due to pests and diseases, it is important to incorporate pest and disease tolerant features as a high objective in maize breeding programme. Crop rotation can be practiced to control pests and diseases (Brust and King, 1994).

2.1.16 *Obaatanpa* Maize Variety

Obaatanpa GH (Reg. no.Cv-1, PI641711) a tropical adapted, intermediate maturing open-pollinated maize (*Zea maize)* cultivar was developed by the Crops Research Institute (CRI), Kumasi, Ghana in collaboration with the International Institute of Tropical Agriculture (IITA), Ibadan, the International Maize and Wheat Improvement Centre (CIMMYT), Mexico, and the Sasakawa Global 2000 (SG2000). *Obaatanpa* GH is a white dent and flint endosperm Quality Protein Maize (QPM) with elevated levels of lysine and tryptophan and was first released by CRI, Ghana in 1992 as *Obaatanpa* to help improve the protein nutrition status and the health of a large population of low- income groups in Sub-Saharan Africa who depend on maize as a major component of their protein intake.

It is also widely fed as porridge to weaning children (2-3 months), until the children are completely weaned (at the age of 15-24 months) and preschool children (3-5 years) without protein supplements. *Obaatanpa* GH has been widely adapted by farmers and consumers in Ghana. Presently, it covers more than 50% of the maize hectarage (650,000 ha) in Ghana (Dankyi *et al*, 2005). It has also been released formerly or informally in several African countries including Benin (as Faaba), Togo, Mali (as Debunyuman), Guinea, Burkina Faso, Côte d'Ivoire, Senegal, Cameroon, Nigeria (as SAMMAZ 14), Mozambique (as Susuma), Uganda, Ethiopia, Zimbabwe, Switzerland, Malawi and South Africa (Badu- Apraku *et al*, 2004). *Obaatanpa* GH has a good level of resistance to the maize streak virus (MSV), lowland rust (incited by *Pruccinia polysora* Undrew), and moderate levels of resistance to blight [caused by *Bipolaris maydis* (Nisikado and Miyake) Shoemaker].

Results of multi-location field tests showed that *Obaatanpa* Gh was superior or comparable in grain yield and other agronomic characters to the top improved intermediate and late maturing normal endosperm maize varieties in Ghana (Twumasa-Afriyie *et al*, 1997; Sallah *et al*, 1997).

2.1.17 Maize production and use in Ghana

Maize was first introduced into Ghana by the Portuguese in the 16th century (Sallah, 1992). Since its introduction, maize has gradually found its way into the traditional system of agriculture in the country. Today, it is the most important cereal crop. The area under maize production has been increasing every year at the expense of rice, sorghum and millet. Maize has been very successful in the southern part of the Interior Savannah Zone where it is preferred to sorghum, either for consumption or as a crop for the growing season (Sallah, 1992). Very early on, maize also attracted the attention of commercial farmers, although it never achieved the economic importance of traditional plantation crops, such as oil palm and cocoa. Over time, the eroding profitability of many plantation crops (attributable mainly to increasing disease problems in cocoa, deforestation and natural resource degradation, and falling world commodity prices) served to strengthen interest in commercial food crops, including maize (Morris *et al.*, 1999).

Today maize is the most important cereal in terms of total production and utilisation in Ghana. The crop is produced in all the five agro-ecologies, namely, the coastal savannah, forest savannah, transition, Guinea and Sudan savannah (Obeng-Antwi *et al*., 2002). It is grown by the vast majority of rural households in all parts of the country except for the Sudan savannah zone. It is commonly grown in an intercropped system involving legumes (groundnut, cowpea) and/or other cereals (sorghum, millet) (Sallah, 1992). As in other African countries, in Ghana maize is cultivated by both men and women.

Maize in Ghana constitutes the primary staple in the areas of production. The bulk of maize produced is processed into indigenous dishes and consumed directly by humans (Sallah *et al*., 2002). It serves as an important source of infant nutrition. It is widely fed to weaning children without any protein supplement such as egg, milk or beans which are relatively more costly. It also features prominently in animal feed and as industrial raw material (NARP, 1993). It is a major source of feed ingredient for poultry and pigs (Twumasi-Afriyie, 1997). Maize in Ghana is consumed in a variety of forms. In the north, it is commonly eaten as a thick gruel, similar to the way that sorghum and millet are consumed. In the south, it is frequently used to prepare porridges and more solid dishes made from fermented or unfermented dough (Morris *et al.*, 1999).

2.2 Tillage and Ploughing

Ploughing is generally considered necessary to loosen and break up the soil in order to increase aeration and water infiltration and prepare a seedbed of suitable tilt for the crops to be grown. Some loosening of the soil is clearly necessary for the seed to be put in the ground and covered up. It is also desirable that the conditions of the seedbed is such that the seed can be placed at uniform depth and in good contact with the soil so that it can readily take up the water, and that there are sufficient wide pores to maintain adequate aeration, and allow easy growth of rootlets. Furthermore, as heavy rains commonly break down clods and soil crumbs, it is usually undesirable to try to produce a fine tilth by tillage and better to leave the land rather rough and cloddy after cultivation (Webster, 1992).

2.2.1 Ploughing Depth

The general objective of deep tillage are to deepen the effective plough zone and depth and also to break through and shatter plough soles and layers compacted by excessive implement traffic, impermeable soil horizons or other barriers to the movement of moisture and roots through the soil profile (Ojha and Michael, 2001).

Previously it was considered that ploughing to a depth of 25 cm or more, on occasion accompanied by subsoil to a greater depth, conferred great benefits through opening up the soil facilitating penetration of water, air and roots (Tempany and Grist, 1958). The cost of production also increases as the amount of earth-work involved in repeatedly loosening, inverting, re-compacting and fertilizer application is indeed very considerable. The consumption of energy, as well as the wear and tear of tractor and implements, increase steeply as the depth of tillage increases. The best management practice usually entails the least amount of ploughing to grow the desired crop. This not only involves a sustainable saving energy cost, but also ensures that a resource base, namely the soil is maintained to produce on a sustainable basis.

Ploughing has various physical, chemical and biological effects on the soil and crops both beneficial and degrading, depending on the appropriateness or otherwise of the methods used. The physical effects such as aggregate-stability, infiltration rate, soil and water conservation, in particular, have direct influence on soil productivity and sustainability (Ofori, 1973). The best tillage system for a field or farm will vary depending on soil type and, on an annual basis, by weather conditions. Since weather cannot be predicted ahead of planting, one has to select a system that will provide a consistently good seedbed across a range of climatic conditions while still maintaining adequate erosion control. A reduction in tillage trips will increase residue cover on the soil surface, and thus reduce erosion potential. Unfortunately, this increase in residue cover may result in cooler, wetter soils that may result in delayed emergence and slower early-season growth. Many farmers are adopting conservation tillage systems not only to reduce erosion potential but also to reduce labour and equipment costs. However, the system selected must have a balance between input cost and consistency of yield over time.

However, effective tillage systems create an ideal seedbed condition (i.e. soil moisture, temperature, and penetration resistance) for plant emergence, plant development, and unimpeded root growth (Licht and Al-Kaisi, 2005). Soil manipulation can also change fertility status markedly and the changes may be manifested in good or poor performance of crops (Ohiri and Ezumah, 1991).

Tillage aims to create a soil environment favourable to plant growth (Klute, 1982). It is carried out with the objective of changing the soil physical properties and to enable the plants to show their full potential. Soil ploughing techniques are used in order to provide a good seedbed and root development, to control weeds, to manage crop residues, reduce erosion and level the soil surface for planting, irrigation, drainage, incorporation of fertiliser or pesticides and harvest operations. Subsoil compaction may reduce the availability and uptake of water and plant nutrients thereby, lowering crop yield. Among the management options for remediation of subsoil compaction is deep tillage Motavilli *et al*. (2003) cited by Khurshid *et al*., (2006**).**

2.2.2 Types of Tillage

Conventional Tillage**:** This involves intensive working of the soil to produce a fine tilth. In mechanised cultivation, the field is ploughed to break up the soil and harrowed to break up large clods of soil resulting from ploughing before the ridges are made. In this tillage, usually, the vegetation may be cleared and allowed to decompose partially or burnt to facilitate digging during which any residues are worked into the soil (Youdeowei *et al.,* 1986).

Conservation Tillage**:** Conservation tillage is an operation that is designed to maintain the roughness of a field surface and leave most of the previous crop residues on the surface while providing a suitable seed-bed and weed control for the next crop. This roughness reduces water runoff and soil erosion (Ikisan, 2000). Conservation tillage, by most definitions, embraces crop production systems involving the management of surface residues (Unger *et al*. 1988; Parr *et al*. 1990). Under conservation agriculture, the number of tillage operations is reduced or entirely eliminated (zero-tillage). Direct sowing is used. Cultivation of green manure (e.g. legumes) is encouraged to enrich the soil. Instead of hoeing to remove weeds, cover crops and residues help to smother emerging weeds. After harvesting, crop residues are left on the land. Crop rotation and intercropping are encouraged in order to break-up pest cycles and to avoid soil exhaustion from continuous mono-cropping. Conservation agriculture has led to maize crop yield increases and greater profitability as production costs are reduced (CKB, 2009).

No-tillage**:** Weed management in no-tillage currently relies heavily upon soil-applied pre-emergence herbicides (Zasada *et al.*, 1997). The modern practice of using herbicides to kill existing grass and other weeds has led to no-tillage. No-tillage describes a practice in which soil disturbance is limited only to the spot where the seed would be placed and for nutrient placement. Planting or drilling is accomplished in a narrow slot created by coulters, row cleaners, or tine openers. Other common terms used to describe no-tillage are direct seeding, zero till, slot till and slot planting (Iqbal, 2006). The surface residues of such a system are of critical importance for soil and water conservation. The entire soil surface is covered by crop residue mulch or killed sod. Several studies (Smika and Unger, 1986; Unger *et al*., 1988; Parr *et al*., 1990) have reported the success of no-tillage systems in many parts of the USA. Though the use of no-till is increasing, adoption has been slow. Parr *et al*. (1990) reported that in the USA, no-till is practised on less than 10% of the farmland that is in some form of conservation tillage.

Mulch tillage**:** Mulch tillage techniques are based on the principle of causing least soil disturbance and leaving the maximum of crop residue on the soil surface and at the same time obtaining a quick germination, and adequate stand and a satisfactory yield (Lal, 1975; Lal, 1986). The use of live mulch and crop residue *in situ* involves special mulch tillage techniques or practices. *In situ* mulch, formed from the residue of a dead or chemically killed cover crop left in place (Wilson, 1978), is generally becoming an integral component of mulch tillage techniques.

Strip or zone tillage**:** Strip- tillage entails the disturbance of narrow strips into the soil where seeding is done and a soil management zone. The seedling zone is mechanically tilled to optimize the soil and micro-climate environment for germination and seedling establishment. The soil management zone remains undisturbed and covered with crop residues as mulch.

Ridge till**:** In ridge tillage, a small band of soil on the ridge is tilled. The soil from the top of the ridge is mixed with crop residue between ridges while weeds are controlled by herbicides. Ridge tillage is characterized by the maintenance of permanent or semi-permanent ridge beds across the entire field. It is primarily intended for the production of agronomic row crops like maize, soybeans, cotton, sorghum and sunflower. The ridge beds are established and maintained through the use of specialized cultivators and planters designed to work in heavy crop residues. In contrast to most forms of mulch tillage, more crop residue remains on the soil surface for a greater portion of the season. Additionally, when done on contour, the ridges themselves largely supplant the need for larger soil conservation structures like terraces on many fields (Kuepper, 2001).

Reduced or minimum tillage**:** This tillage system involves considerable soil disturbance, though to a lesser extent than that associated with conventional tillage. Some crop residues is left on the soil surface. In Africa, the term minimum tillage is not always employed with the same meaning as in temperate countries, and may also be used differently in the different contexts of shifting cultivation (still the dominant system in most African countries) and mechanised agriculture (Ahn and Hintze, 1990).

2.3 Soil Properties

2.3.1 Soil texture

Soil texture: The most fundamental soil property, one that most influences other soil traits, is texture. Soil texture describes the proportion of the three sizes of soil particles- sand, silt and clay. This affects water-holding capacity and aeration (Plaster, 2002). Soil texture can be measured by mechanical analysis of a sample in the laboratory and classified accordingly and also by a "feel" test (Lockhart, 1988). The soil particles are divided into three groups. Sand particles are 0.2 – 0.05mm in diameter. Silt has particles that range in diameter from 0.05 – 0.002mm, and clay particles have diameters smaller than 0.002mm. Most soils contain some material from each size group and soil texture is determined by the relative proportion of these types of particles. Soil texture is of agricultural importance because texture influences water and air movement in the soil and also determines energy required for soil cultivation (Walton, 1988).

2.3.2 Soil structure

Soil structure- The arrangement and organisation of the particles in the soil is called soil structure (Hillel, 1980). This can be altered by weather conditions, penetration of plant roots, cultivation, etc (Lockhart, 1988). Structure directly affects many of the properties of soil. Water retention and conductance are dependent on pore space and pore sizes. It influences ploughing operations because of the properties of individual particles are more or less masked in stable aggregates which can thus give a favourable physical condition to soil that would otherwise be intractable. It also affects the environment for roots through its effects on water and oxygen supply and soil strength. Growth of plants can be severely retarded or wholly prevented by structure that is grossly unfavourable to water or air movement or resistant to seedling emergence or root growth (Marshall and Holmes, 1988).

2.4. Soil Physical Properties

2.4.1. Porosity

Total pore space is a measure of the soil volume that holds air and water. The value is usually expressed as a percentage and is known as porosity. Soil porosity is part of the property known as soil structure which includes the arrangement of particles in aggregates, and the size, shape and distribution of the pores both within and between the aggregates. If the particles lie close together as in sandy soils or compact subsoil, the total porosity is low. If they are arranged in porous aggregates, as is often the case in medium-textured soil high in organic matter, the pore spaces per unit volume will be high (Brady and Weil, 1999). Porosity depends on the water content of the soil, since the volume of pores and the total volume of an initially dry soil may change differently due to swelling as clay surface hydrates or shrinkage as the soil dries (White, 2006).

2.4.2 Ploughing Effects on soil porosity

Soil porosity characteristics are closely related to soil physical behaviour, root penetration and water movement (Pagliai and Vignozzi, 2002; Sasal *et al*., 2006). Porosity characteristics differ among tillage systems (Benjamin, 1993). Previous researchers showed that straw returning could increase the total porosity of soil (Lal *et al*., 1980) while minimum and no tillage would decrease the soil porosity for aeration, but increase the capillary porosity; as a result, it enhances the water capacity of soil along with bad aeration of soil (Wang and Wen, 1994; Glab and Kulig, 2008). However, Borresen (1999) found that the effects of tillage and straw treatments on the total porosity and porosity size distribution were not significant.

The processes considered dominant for the formation of soil porosity differ between tilled and untilled cropping system. In tilled cropping system pores are formed by the arrangement of the solid phase by the tillage tool. In the no-tillage system the pores are formed primarily by biological activities with the action of earthworms and roots playing a significant role. Since different methods of creation of pores are used, the pore-size distribution and pore continuity would be expected to vary between tilled and no-tilled systems (Benjamin, 1993). Roserberg and McCoy (1992) found that conventional tillage increased total porosity of the soil, but the macro-pores decreased in number, stability and continuity compared with no-tillage soils.

Tillage resulted in the distribution of soil porosity with time and soil under no-tillage had a larger proportion of water filled pores than did conventionally tilled soil. This might be due to better soil aggregation under no-tillage system (Shukla *et al*., 2003). Although the soil of the no-tillage system had higher bulk density in the surface layer and lower total porosity and less macro-pore volume, it probably had limited effect on soil water recharge and drainage because of higher amounts of residue on the soil surface (Bhattacharyya *et al*., 2005) cited by (Iqbal, 2006).

2.4.3 Bulk Density

Bulk density is defined as the mass of oven-dry soil per unit volume, and depends on the densities of the constituent soil particles (clay, organic matter, etc.) and other packing and arrangement into peds (White, 2006). The volume includes both solids and pores. The bulk densities of soils depend mostly on the amount of pore space in the soil, since particle weight is fairly constant. Bulk densities of mineral soils usually range from 1.0g per cubic centimetre for 'fluffed-up' clay soils to 1.8 g cm^{-3} for some sandy soils. Organic soils are much lighter, with values of 0.1 to 0.6 g cm^{-3} being common (Plaster, 2002).

Bulk density is inversely related to total porosity (Carter and Ball, 1993), which gives us an idea of the porous space left in the soil for air and water movement. The optimal bulk density for plant growth is different for each soil. In general, less than optimal bulk density (high porosity) leads to poor water relations, and high bulk density (low porosity) reduces aeration and increases penetration resistance, limiting root growth (Cassel, 1982).

Soils with a high proportion of pore space to solids have lower bulk densities than those that are more compact and have less pore space. Consequently, any factor that influences soil pore space will affect bulk density. Fine-textured soils such as silt loams, clays and clay loams generally have lower bulk densities than do sandy soils. This is true because the soil particles of the fine-textured soil tend to be organised in porous granules, especially if adequate organic matter is present. Thus in these soil pores exist both between and within the granules. This condition assures high total pore space and low bulk density. In sandy soils, however, organic matter contents generally are low, the solid particles are less likely to be aggregated together, and bulk densities are commonly higher than in the finer-textured soils. While sandy soils generally have high bulk densities, the packing arrangement of the sand grains also affect their bulk density. Loosely packed grains may fill as little as 52% of the bulk density volume, while tightly packed grains may fill as much as 75% of the volume (Brady and Weil, 1999). The bulk density is generally lower if the sand particles are mostly of one size class, which a mixture of different sizes is likely to have as especially high bulk density. In the latter case, the smaller particles partially fill in the spaces between the larger particles. The most dense materials are those characterised by both a mixture of sand and tight packing arrangement (Brady and Weil, 1999).

2.4.4 Ploughing Effects on Soil Bulk Density

Ploughing is one of the major causes of soil erosion and physical degradation of the soil. This operation loosens, granulates, crushes, or compacts soil structure, changing soil properties such as bulk density, pore size distribution and composition of the soil atmosphere that affect plant growth. Ploughing may have a profound effect on soil bulk density depending on the time when tillage was done. Soil bulk density values showed a significant difference among tillage treatments in the top 12 cm of soil in a study conducted in Montana on a Typic Argiboroll in a wheat-fallow chisel tillage versus annual no-tillage system. The maximum bulk density of soil in the chisel was 1.61 Mg m^{-3} compared to 1.55 Mg m^{-3} in the no-tillage treatment. The zone of maximum soil bulk density roughly corresponded to the depth of tillage (Pikul and Aase, 1995). Ploughing leads to breakdown of aggregates and conversion to conventional tillage can lead to increase in aggregation (Hamblin, 1980). Blevins *et al.* (1977) measured soil bulk density between no-tillage and conventional tillage plots and found no difference between them in the surface horizon. In continuation of this study, Blevins *et* *al.* (1983) also observed no difference in soil bulk density in a long-term study due to tillage treatments. In contrast, previous research with long-term tillage systems indicated that soils under no-tillage had greater soil bulk density than those under conventional tillage (Salinas-Garcia, 1981). In a similar study in Maryland, bulk density of soil was measured three weeks after planting in continuous maize for five years between no-tillage and conventional tillage. Soil bulk density was greatest with no-tillage compared to conventional tillage (Griffith *et al.*, 1986). Measurements after harvest showed only slightly higher bulk density in the no-tillage than conventional tillage treatment. No-tillage practice can result in increased bulk density in the surface to 25 cm or 25-30 cm depth of soil (Gantzer and Blake, 1978). In general, no-tillage results in greater bulk density than conventional tillage due to the absence of tillage to relieve soil consolidation and compaction caused by farm machinery (Francis *et al*., (1999) cited by Iqbal, (2006)). Logsdon *et al*. (1999) concluded that no-till did not result in more dense soil compared with tilled unless traffic was controlled in tilled. Brady and Weil (1999) reported that bulk density of the top 0.3 m was greater in a sandy loam soil and clay soil for no-tillage compared with conventional tillage or reduced tillage. Vyn and Raimbaault (1993); Cassel *et al*., (1995) have reported greater bulk density and soil penetration resistance and lesser total porosity in no-tillage compared with tilled during maize growth.

2.4.5 Effects of ploughing on crop performance

Breaking up the hard pan enables plants roots to penetrate lower soil regions to obtain available moisture and nutrients. Deep tillage breaks up high-density soil layers, improves water infiltration and movement in the soil, enhance root growth and development, and increase crop production potentials (Bennie and Botha, 1986). Varsa *et al*. (1997) concluded that deep fracturing and loosening of the naturally formed fragipans by deep tillage up to 40 cm was important in improving root penetration for maize production. Nitant and Singh

(1995) indicated that deep tillage treatment was superior to shallow tillage treatment in increasing the crop yield. The deep tillage treatment gave the highest yield over the other treatments. Ojha and Micheal (2005) reported that research conducted on depth of ploughing have revealed that deep ploughing to the depth of 15-20 cm is beneficial. He also stated that conventional tillage contributes to pest control by destroying some perennial weeds, disrupting the life cycle of some organisms, contribute to soil erosion and require more energy.

Minimum tillage practices have been observed to slow plant growth, reduce plant dry weight and delay maturity (Wall and Stobbe, 1983). According to the results of trials, reduction of soil tillage intensity had no significant influence on the yield of many crops (Ekeberg, 1993; Håkansson *et al.,* 1998; Hao *et al.,* 2001). The zero tillage system mostly showed the decrease of crop yield but sometimes the converse influence (Riley *et al*., 1998; Riley, 2005) was observed. Reduced tillage may lead to increased weed infestation, especially of perennials (Munkholm *et al*., 1998; Draycott, 2006). In some trials the increase of weed number had a negative influence on crop yield (Børresen, 1993). Surface residues can contribute to cooler soil temperatures (Gauer *et al.,* 1982) and inhibit the root growth of a germinating crop because of phytotoxin produced (Cochran *et al*., 1977).

2.4.6 Effects of ploughing on root length

The distribution of roots in the soil profile is often dependent upon the tillage system implemented. Roots of plants growing in conservation tillage systems are more concentrated at shallower depths than plant roots grown in other tillage systems. This difference in distribution is attributable in part to the higher soil moisture levels near the surface in conservation tillage. Important also is that without soil mixing, nutrients become more concentrated near the soil surface. Such nutrient distribution contributes to the concentration of roots nearer the soil surface.

The continuous ploughing of soil at shallower depth results in development of plough pan which restrict nutrient movement and root penetration. Therefore, deep tillage practices is also very important to remove this compact layer (Iqbal, 2006). According to Nitant and Singh (1995) deep tillage with disc ploughing and sub-soiling also induced deeper root penetration by 34 and 39 cm resulting in 89 and 127% respectively, more grain yield than the shallow tillage by country plough.

2.4.7 Ploughing Effects on air content

The gaseous phase of soil acts as a pathway for intake of oxygen which is absorbed by soil micro organisms, plant roots and for escape of carbon dioxide produced by the plants. This two way process is called soil aeration. Soil aeration becomes critical for the plant growth when water content is high because water replaces soil air (Ikisan, 2000).

Tillage affects aeration and thus the rate of organic matter decomposition. Biological activities in the soil are vital to soil productivity through the activities of earthworms, termites and the many other living creatures in the soil whose presence is largely dependent on the air content. These influence water infiltration rates by their burrowing in the soil and their mucilage promotes soil aggregation. By passing over the field frequently at ploughing, tractors and other heavy equipment compact the soil, reducing aeration and the number of soil organisms. Ploughing during seedbed preparation stirs and loosens soil, improves air content, and creates a suitable medium for plant growth. Reicosky and Lindstrom (1993) indicated major gaseous loss of soil carbon as carbon dioxide immediately after tillage. Deep ploughing reduces aggregate size and exposes more surfaces to microbial attack, which stimulates oxidation and accelerates removal of carbon rich surface soil by erosion.

2.4.8 Ploughing effects on soil moisture content

In order to function as a medium for plant growth, soil must contain some water to promote many physical and biological activities of the soil. Water also acts as a solvent and carrier of nutrients, as a nutrient itself, acts as an agent in photosynthesis process, maintains turgidity of plants and acts as an agent in weathering of rocks and minerals (Ikisan, 2000).

Soil moisture is a critical issue in conservation tillage. Management systems such as no-tillage and minimum tillage are effective means in reducing water loss from the soil and improving soil moisture regime (Hatfield and Stewart, 1994). Soil pore geometry (pore-size, shape and distribution) and soil structure are affected by tillage and influence soil water storage and transmission (Azooz *et al*., 1996). Some researchers have found no or negative effect of tillage on soil water transmission characteristics (Obi and Nabude, 1988), while others found greater beneficial effects of no-tillage on soil water retention properties than conventional tillage (Datiri and Lowery, 1991).

Tillage influences the upward movement of moisture to the soil surface, vapour transfer from the surface to the atmosphere and heat transfer to the soil. Tillage therefore, affects soil water evaporation and will do so differently in arid and humid environments. The properties of the plough layer and particularly the surface characteristics are time variant. Models of soil water transport can and have been used to help understand the effects of tillage (Klute, 1982). Tillage encourages soil protection and care through reduced tillage practices and the maintenance of surface residues. This minimizes soil disturbance, encourages build-up of organic material, preserves the soil structure, and conserves soil water (MacRobert *et al.*, 2007).

2.4.9 Ploughing effects on weed growth

Ploughing is seen as a method by which weed seeds can be buried below the depth from which they are capable of germinating, and it is sometimes said that ploughing is needed only to bury the weed problem. But this short-term solution to poor weed control in a previous crop often leads to long term problems due to the persistence of the buried weed seeds in the soil seed bank (Bond and Turner, 2007). The mouldboard plough is the traditional implement for burying weeds and crop residues as ground preparation for establishing a new crop (Lampkin, 1998).

Tillage alone or in combination with good cropping methods is often the best and most economic method of weed control (Lal, 1979; Robinson *et al.*, 1984). Tillage directly affects the seed bank by physically mixing the soil (Ball and Miller, 1990). Tillage may help in managing herbicide resistance weeds and may also increase weed density as well as reduce crop yield (Anderson (2004) cited by Chokor *et al.* (2008)).

2.5 Weeds

A weed is a plant that in a given situation is detrimental to agriculture rather than beneficial (Walton, 1988). Weeds have been a problem to humans ever since cultivation of crops began (Hay, 1974). They grow very rapidly and luxuriously in the rainy season, competing strongly with crops for water, nutrients and light. Weed competition is particularly problematic in arid and semi arid zones, since moisture lost to weeds translates directly to yield losses in the maize crop (Raemaekers, 2001). Similarly, Rao (2000) noted that weeds can deprive crops of 30 - 50% of the applied nutrients and 20-40% of soil moisture. In the tropics, weeds cause more crop losses and farmers spend more of their time weeding crops than in any other part of the world. Weeds form a major factor which contributes to the miserable quality of life of smallholder farmers, especially of women and children, in rural areas of sub-Saharan Africa (Mashingaidze, 2004).

2.5.1 Weed characteristics

Knowing what weeds are common on a particular farm will help to determine what lessons can be learned and what management strategies might be effective against them. Most weeds have some characteristics in common. The unique characteristics of weeds have made them difficult to control in the field. The following are some characteristics of weeds.

Rapid Vegetative Growth

Many weeds develop rapidly, are able to self-pollinate, disperse widely and tolerate a wide range of environmental conditions. A study in 1980 indicated that despite enormous effort, weeds have steadily increased from 1900 to 1980 (Frick, 2002). Weeds have numerous tillers for grasses, rapid tuber and shoot formation for sedges, and faster stem elongation and branching for broad leaves. Also, weeds can reproduce sexually and asexually and because of this, weeds are able to maintain high population densities if not managed effectively. They also mature early so they are able to reach their reproductive period at a lesser time, hence more weed plants are capable of reproducing.

Very Prolific

Weeds have the ability to produce profuse flowers in a short period, and have a very high percentage of seed setting that result in large numbers of seed formation. Perennial weeds can reproduce rapidly through vegetative means through tubers, rhizomes and stolon.

Ability to Survive and Adapt to Adverse Conditions

Weeds are capable of resisting drought and excessive moisture stress. Beans (2009) stated that large crabgrass (*Digitaria sanguinalis*) form contractile roots and arrests its growth during extremely dry conditions and resume their normal conditions until a favourable condition is met. The common purslane (*Portulaca oleracea*) incline their leaflets upward to reduce exposure to sun during dry conditions thus reducing excessive moisture loss due to transpiration.

Dormancy

Dormancy is a mechanism that enables the weed species to survive under unfavourable conditions. This mechanism is common to weed species and until a favourable condition for growth is observed. Weed seeds can often germinate under a variety of conditions, but some portion of the seed population remains dormant. Even though 95% of the weed seeds in the soil ‘seed bank’ may be lost to germination or death, the seed bank can often recover in a single year (Schreiber, 1992).

Adapted to Crop Competition

Weeds have proper synchronized germination. They are able to germinate at the right time in favourable environments. Their seedlings are fast growing and can be rapidly established. Their quick response to moisture and nutrient availability make them well adapted to crop competition in the agro-ecosystem.

2.5.1 Classification of Weeds

Weeds may be generally classified as either grass or broadleaf weeds.

2.5.1.1 Characteristics of Grass Weeds

Grass weeds commonly found in a crop field can be identified by looking for specific characteristics of the plant. These specific characteristics can include, but are not limited to, the width of the leaf blade, presence or absence of hairs, growth habit, type of seed head, root system, and plant size. The entire leaf can be further divided into the sheath, ligule, and blade to also aid in identification. The sheath is the lower part of the leaf that fits around the stem. The projection at the base of the leaf blade is called a ligule. The ligule may be either a membrane or a fringe of hairs or a combination of both. Additionally, the presence of other factors such as stolons (above ground stems) or rhizomes (underground stems) can also be helpful in plant identification (Futch and Hall, 2008).

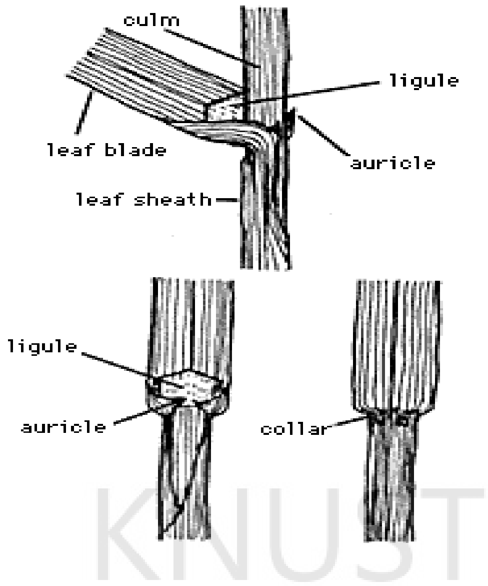

Fig. 2.1: Vegetative grass parts

Any or all of these vegetative characteristics may be useful to help identify a young grass weed as shown in Fig. 2.1.

1. Grass seedlings have one leaf as they emerge from seed

2. Leaves are generally narrow and pointed at the tip, grow upright, and have parallel veins in the leaf blade with an expanded leaf blade portion and a leaf sheath portion toward the base that encircles the stem **(**Strand and Miller, 2002)

3. Grasses are either annual that grow and develop with a fibrous root system that lacks a central taproot or perennial, producing rhizomes, rootstocks, or stolons

4. The stems are round and can be either hollow or solid

5. The leaves are arranged on two alternate rows on the stem and

6. Some grasses also have claw-like or hook-like projections at the leaf collar called auricles that may partially encircle the stem

2.5.1.2 Characteristics of Broadleaf Weeds

Fig. 2.2 portrays vegetative broadleaf plant parts. All of these characteristics help in identification of broadleaf weed seedlings:

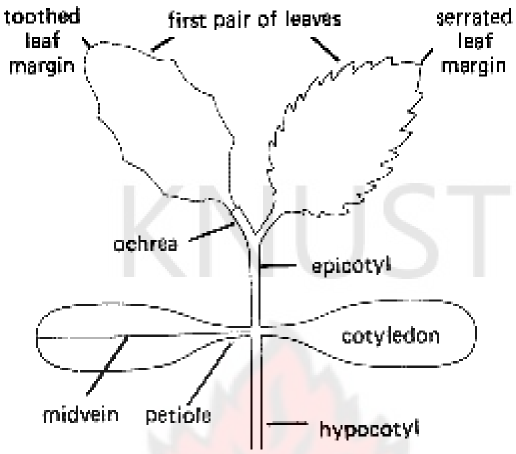

Fig. 2.2: Vegetative broadleaf plant parts

1. Broadleaf weed seedlings, in contrast to the grasses, usually have wider leaves with net-like venation

2. Broadleaves are dicotlydons and have two cotyledons or seed-leaves, which usually emerge above the soil and expand to become the first visible "leaves." The true leaves then develop above the cotyledons. However, in some broadleaf species, the cotyledon (seed) remains in the soil and the plumule (growing point and cluster of undeveloped true leaves) emerges above the soil line

3. Leaves may be alternate or opposite in arrangement on the stem. In some cases the second leaf may appear so closely behind the first leaf that they appear to be opposite but later prove to be alternate

4. The true leaves of broadleaf weeds usually have a petiole (leaf stalk), but in some species the true leaves may be sessile (without a leaf petiole)

5. Cotyledons are usually hairless but may be rough, while true leaves and plant stems may be hairy or smooth and

6. Broadleaf weed seedlings may have an erect stem, be viny or twining in growth habit, or may be prostrate (growing flat on the ground)

2.5.2 Weed types

Weeds are placed in three groups based on their life cycle: annual, biennial, and perennial. Annual weeds: These weeds complete their life cycle within a year. All parts of annual weeds die at the end of flowering and seed production, including the roots. These roots are usually relatively shallow and fibrous, making them easy to pull up.

Biennial: Biennial weeds require two years to complete their life cycle. They emerge, grow and store food in the first season. During the second season they draw on the stored food to produce vigorous vegetative growth to produce mature seeds.

Perennial: Perennial weeds can live for several years; at the end of the growing season the leaves die back, but the roots and underground parts survive and the foliage re-emerges the following year. These weeds either have deep tap roots or extensive root systems and unless every part of the root system is removed or killed, the weeds will grow again. They can also regenerate from stem tissue and many set seed, as well.

2.5.3 Weed Control Methods

Weeds have been present ever since man started to cultivate crops, and they were undoubtedly recognised as a problem from the beginning (Hay, 1974). When man first started to grow crops for food and fibre, he soon learned that yields were much higher when weeds were removed to allow only crop plants to grow. Thus the concept of weed management is as old as agriculture itself (Rao, 2000). The control of weeds has always been one of the greatest resource-consuming operations in crop production. In addition to requiring effective control measures, weeds rob crop plants of nutrients and water, often serve as hosts to insects and other pests, and create problems in harvesting and processing (Abu-Hamdeh, 2003). Weeds are one of the most important factors in maize production. They cause important yield losses worldwide with an average of 12.2% despite weed control (Oerke and Steiner, 1996). Therefore, weed control is an important management practice for maize production that should be carried out to ensure optimum grain yield (Doğan *et al*., 2003).

Because of the harmful results weeds have on crop yield, it is helpful to keep populations low. Weed control is essential for an acceptable crop yield and economic income. Effective weed control often requires a combination of cultural, mechanical and chemical applications is one important component of integrated weed management (Abouziena *et al.*, 2007).

2.5.3.1 Mechanical weed control

Hand pulling: Pulling of weeds is an efficient and practical method of controlling weeds in most cropping systems. It is a common method in small holding through the tropics and requires little or no investment in farm tools; it relies on cheap and abundant labour. Because hand-weeding is generally delayed until weeds are well established, some competition is inevitably associated with most hand-weeding operations (Youdeowei *et al*., 1986). This method is better applied to annual and biennial weeds because they cannot regenerate through pieces of roots left in the ground. In the case of perennial weeds the method has to be repeated from time to time in order to make it effective.

Hand hoeing: This is one of the common method of weed control. The hand hoe very often accomplish results that cannot be achieved effective and cheaply in any other way. In most parts of Africa the hand hoe is widely in use to control weeds in small scale farms. It has been demonstrated that even persistence weeds can be eradicated using the hoe.

Slashing: This may be successful in the control of tall weeds. Though it is a very quick method but may encourage the growth of creeping and low growing weeds. A cutlass is a good example of a tool used in slashing. This method is very useful in very steep slopes where tillage would subject the soil to serious erosion (Beinempala *et al*., 1988).

Tillage: It controls weeds of all classes. If it is properly implemented, weeds cannot flower and produce seeds. The first surface tillage creates a suitable stubble environment for the germination of weed seeds. A second tillage destroys seedlings. Tillage is effective against annuals and shallow-rooted perennials, but small fragments of some species, particularly those perennials with rhizomes, can often re-sprout following tillage. Tilling should be completed before seeds develop and are shed onto the soil. The best control is achieved when the soil remains dry, so that the remaining plant fragments dry out. Moist soils help the fragments survive and re-grow (Tu *et al.*, 2001). Deep tillage with the aim of burying down the weeds may not be a good practice as some of the weed seeds can remain dormant deep in the soil. Subsequent tillage operation may bring the weed seeds to the surface where they germinate (Bienempala *et al*., 1988).

Soil cultivation or tillage in its various forms has long been the mainstay of weed control and is the most effective way to reduce the weed seed bank. Seeds are encouraged to germinate and then the soil is cultivated mechanically to kill off the plants. The mouldboard plough is the traditional implement for burying weeds and crop residues as ground preparation for establishing a new crop. Adams (2006) reported that the annual loss of seeds from a natural soil weed seed-bank (with no addition of fresh seed) was 22% with no cultivation. When the soil was cultivated twice a year the annual loss was 30%, and when cultivated four times it was 36%. However, it is not just the cultivations associated with the post-harvest incorporation of crop and weed residue that have weed control benefits. The method, depth, timing and frequency of cultivation may influence the composition, density and long-term persistence of the weed population.

2.5.3.2 Cultural

Crop spacing: Plants spaced closely together will develop cover quickly and shade the weeds that try to grow. However, crop spacing should not be too close so as to cause negative competition between the crop plants.

Cover crops: Growing cover crops that develop quickly will help to suppress weeds before they grow. Some cover crops (legumes) control weeds by preventing (smother) them from growing.

Mulching: Mulch is an extremely effective means of controlling weeds, especially the annual varieties. In addition, mulching conserve soil moisture, keeping the soil at a uniform temperature, preventing erosion, and creating a more attractive farm appearance. Good mulch prevents the light from reaching the seeds which are sprouting at the soil level. Mulch needs to be carefully selected not to include weed seeds; otherwise they may introduce more weeds into the field.

Crop rotation: Crop rotation helps to break the life cycle of certain weeds common to a particular crop. It also results in vigorous growth of the crop. Moreover, one type of crop has its own weeds and by not repeating the crop year after year, such weeds may not appear on the field. In addition, the soil is subjected to different treatments for different crops.

Burning: During land preparation the land is set on fire before or after slashing. This kills both weeds and their seeds if the fire is hot enough. It is a common method of controlling weeds in subsistence agriculture before planting.

2.5.3.3 Biological

The biological method involves the use of some suitable insects or some other organisms on the crop field to control weeds. They selectively destroy the weed plants but do not harm the crop plants (Vista, 2008). The objective is to introduce in an area an insect species that attack one or more weeds but leaves the crop plant unharmed (Walton, 1988). The goal of biological control is not eradication, but the use of living agents to suppress vigour and spread of weeds. Such agents can be insects, bacteria, fungi, or grazing animals such as sheep, goats, cattle or horses. One must realize that eradication of a weed cannot be attained through insect bio control. The most effective scenario is a weed infestation reduced to a 'tolerable level', a level where the insect agents are significantly limiting distribution and abundance of the target weed species and the weed density is no longer considered detrimental to the desired plant community (Larimer, 2010).

2.5.3.4 Chemical

Sometimes the only option to kill the existing vegetation is to use chemicals. Products, like systemic herbicides, meaning they are absorbed through the plants vascular system and get down into the roots, to kill the whole plant and selective herbicides (those used to control broadleaf weeds) are often used. They are considered selective since they only kill selected, or target weeds, when they are properly applied. Applying the proper rate is very important since a higher rate may not be selective, killing more than just the target weeds. Non-selective herbicides can kill any plant they touch, without being at all selective.

While chemical weed control is a common practice in commercial agriculture, it is hardly applied in smallholder farming due to several limiting factors, especially access to herbicides and sprayers, costs, availability of clean water in the field, and knowledge/expertise of appropriate and safe handling of herbicides. However, appropriate training and access to herbicides provided, chemical weed control is a real option for smallholder farmers. Increasing labour shortage and costs of labour makes chemical weed control an attractive alternative for small farmers in many regions (Steiner and Twomlow, 2003).

2.5.3.5 Prevention

These are measures adopted either before or during the planting of a crop which allow the crop plant to establish itself well so that it can compete favourably with the weeds. Thus, preventive measures aim to improve the environmental conditions of the crop plant so as to promote vigorous growth.

Destroying the weeds before they set seeds is a very good method of weed prevention. Planting weed-free seeds is another important practice. Seeds to be used the following year should be thoroughly cleaned off weed seeds to avoid field contamination. Contaminated crop seeds will increase weed population on the field therefore increasing their competition with crops.

Using clean equipment on the farm also helps to control weeds. Although the farmer has no control over most transportation machinery, much can be done to reduce the spread of weeds with his own agricultural machinery. All kinds of farm equipment are responsible for spreading weed seeds and vegetative organs from field to field and from farm to farm. Various types of seedbed-preparation equipment scatter vegetative organs of weeds over the fields. During transport to other farms, vegetative organs may adhere to tillage implements and become dislodged when the equipment is used again. Keeping the field margins clean to prevent weed invasion from nearby fields is also very important in weed control.

2.5.4 Weeding tools

Cutlass**:** The cutlass is a multi-purpose tool, used in clearing the bush (slashing and cutting), planting (digging holes with the blade end), weeding (turning over the soil with the blade end) and harvesting (cutting and digging) (McNeill and O'Neill, 1998). Cutlasses were the early steel tools for weeding. However, weeding with a blade only severed a weed at the soil surface and failed to destroy the root system, resulting in rapid re-growth. Annual grasses retain a growing point near the soil surface and perennials re-grow from underground meristems.

Weed Wiper**:** Is a simple tool that works just by gravity. A plastic container fixed on top of the handle is filled with a premixed herbicide solution. The herbicide drips through the handle to a foam-coated "brush" and is applied by touching the weeds with the foam-coated "brush". Unlike sprayers there is no danger of drift affecting the crop (Steiner and Twomlow, 2003).

Knapsack Sprayer**:** Is used to control all types of weeds in the field. It has a tank from which the chemical is pumped for application. If properly used, it can be very effective in weed and pests control.

Handheld hoe**:** A hoe is a tool used for cultivating, weeding, and breaking up the soil. It has a short or long wooden handle attached to a thin, flat metal blade. Depending on the type and weight, hoes may be used with a chopping, pulling, pushing, or pull-push motion. There are many types. A hoe will work best if its blade is kept sharp, and it should be cleaned after each use and protected from the weather to prevent rust.

2.5.5 Effects of Weeds on crops

Weeds growing among crop plants adversely affect yield and quality of the harvest and increase production costs, resulting in high economic losses (Alam, 1991). They compete with the main crops for nutrients and other resources and hamper the healthy growth ultimately, reducing the yield both qualitatively and quantitatively. Roberts and Chancellor (1980) and Sen *et al*., (1984) cited by Jabeen and Ahmed (2009) mentioned that weeds caused more loss to agriculture than all pests, put together. In arable crops most damage is caused by annual weeds, but in established grassland biennial and perennial weeds causes a reduction in yield, nutrient quality and palatability of the sward (Lockhart and Wisemans, 1988).

Weeds are fast growing. They compete with crops for solar radiation, water, nutrients and space. Different intensities of crop yield losses caused by weed competition have been observed: 21% (Hussein, 1996); 90% (Dalley *et al.*, 2006); and 66% (Abouziena *et al.*, 2007). Certain weeds provide hiding place for insect-pests and act as host plants for certain pathogens which might in turn affect the crop leading to losses in yield: insects such as aphids, thrips, weevils, and flies. Weeds also interfere with the harvest of crop plants. Large weeds may clog machinery and slow down harvesting. Produce that is hand-harvested may be hidden by weed vegetation and may get left in the field. Some weed plants secrete harmful chemicals that may have harmful effects on crop plants, soil or human being (Ikisan, 2000). Weeds reduce the value of the land Agricultural lands heavily infested with perennial weeds always fetch less price.

3. MATERIALS AND METHODS

3.1 Experimental Site Description

This study was conducted at the field near the Plantation Section of the Department of Crop and Soil Sciences at Kwame Nkrumah University of Science and Technology, Kumasi (latitude 6° 41' 0" N, longitude 1° 33' 3" W and altitude 295.7 m above sea level) in Ghana during the 2009 major crop growing season. The area had been previously sown to maize for one year and cowpea for one year prior to the start of the experiment. The climate at the site is distinguished by a bi-modal rainy season from March to July and from September to November, when most of the rain falls as heavy convectional storms, followed by a dry season from November to February. The average rainfall is about 1300 mm. The daily maximum temperature ranges between 31 and 39 ^{o}C. Table 3.1 shows the precipitation at the study area between 2002 and 2009.

Table 3.1: Average precipitation at the study area: 2002–2009

	Precipitation (mm)							
Month	2002	2003	2004	2005	2006	2007	2008	2009
January	0.0	15.3	32.8	8.1	109.7	8.4	0.0	0.0
February	14.6	99.8	32.0	45.5	113.9	65.3	61.7	114.9
March	156.0	26.1	87.2	84.6	91.4	76.7	134.1	162.9
April	193.9	160.4	109.6	126.5	93.2	189.9	117.1	123.9
May	158.0	142.3	81.1	172.1	143.9	84.3	185.8	99.0
June	299.5	150.7	60.3	93.0	113.0	244.2	179.9	367.9
July	273.5	176.3	109.7	22.8	68.0	374.0	45.0	226.1
August	100.3	62.3	73.7	35.6	75.8	127.3	114.5	19.0
September	168.5	189.0	326.4	169.2	96.8	539.8	148.9	59.7
October	191.7	206.7	171.2	224.6	117.1	237.6	95.8	201.7
November	48.9	139.9	37.6	54.5	60.2	48.6	30.7	40.4
December	22.1	14.5	110.5	0.0	5.4	2.9	47.5	30.0
Total	1627.0	1383.3	1232.1	1036.5	1088.4	1999.0	1161.0	1445.5

Table 3.2 presents the average maximum air temperatures (^oC) at the study area between 2002 and 2009. Table 3.3 presents the average minimum air temperatures (^oC) at the study area between 2002 and 2009.

Table 3.2: Average maximum air temperature ^oC at the study area: 2002–2009

	Maximum Air Temperature ^oC							
Month	2002	2003	2004	2005	2006	2007	2008	2009
January	33.5	33.1	32.6	32.4	32.6	34.0	33.3	33.5
February	35.0	34.5	34.2	35.1	35.0	34.5	34.6	33.8
March	33.8	35.0	32.6	34.1	32.9	35.2	34.2	33.5
April	33.4	33.4	32.4	34.2	34.3	34.0	33.3	33.4
May	33.6	33.6	30.7	32.5	32.2	32.9	33.0	33.0
June	31.2	30.8	29.1	30.6	31.4	31.6	31.4	31.7
July	29.5	29.9	29.6	29.3	30.3	29.6	28.8	29.6
August	28.4	28.9	30.6	28.4	29.2	29.9	29.5	28.6
September	30.0	29.5	31.0	30.7	30.1	30.2	30.0	30.0
October	31.1	31.5	31.0	31.8	31.5	30.9	31.3	31.1
November	32.5	31.9	31.7	32.0	32.3	31.4	32.7	35.8
December	32.3	31.5	31.9	32.1	32.7	32.1	32.0	32.9

Table 3.3: Average minimum air temperature ^{o}C at the study area: 2002–2009

	Minimum Air Temperature ^{o}C							
Month	2002	2003	2004	2005	2006	2007	2008	2009
January	18.5	20.7	20.5	16.3	21.2	16.5	19.2	20.3
February	22.0	22.1	20.6	22.6	22.5	22.4	21.7	22.5
March	22.6	22.1	22.5	22.0	21.8	22.6	22.6	22.7
April	22.8	22.0	22.5	22.9	22.5	22.0	22.9	22.5
May	22.5	22.3	21.2	22.5	22.0	22.6	22.8	22.7
June	21.9	21.5	20.5	21.7	20.6	22.9	22.5	22.1
July	21.8	20.7	20.5	20.7	20.8	22.1	22.3	21.4
August	20.3	20.5	20.8	20.3	20.5	22.1	20.8	21.7
September	21.0	20.9	21.8	21.1	21.1	22.1	21.3	21.9
October	21.6	21.8	21.9	21.6	21.7	21.9	21.6	22.1
November	21.7	21.7	22.9	22.0	21.8	22.1	22.2	22.4
December	19.5	20.2	22.1	21.5	21.8	19.9	21.1	23.0

3.2 Experimental Design

The experimental design consisted of a factorial arrangement of four ploughing depths and five weed control treatments. The layout consisted of three blocks, with twenty plots in each block, assigned in a randomised complete block design. The treatments were ploughing depths at 0 cm, 10–15 cm, 15–20 cm and 20–25 cm. The weed control treatments included weed control with a hand hoe, cutlass, weed wiper, knapsack sprayer, and no weed control. Altogether, there were 60 plots. Each plot measured 4m x 4m. There was a buffer zone of 1.5 m between plots. The buffer zone was there to prevent the crops from merging when they matured. The buffer zone also helped to distinguish between the different plots. The experimental design layout is presented in Appendix 1.

3.3 Land Preparation and Sowing

The experimental field was slashed on 4 May, 2009, disc ploughed on 27 May, 2009 and disc harrowed on 29 May, 2009. *Obaatanpa* maize variety seeds were obtained from Crops Research Institute (Council for Scientific and Industrial Research). The number of seeds sown per hill was two seeds at a depth of 5 cm with a custom made depth controlled dibbler (Aikins *et al*., 2006). The recommended plant spacing of 80 cm by 40 cm was used resulting in a plant population of 100 plants/plot (16m^2) or 62,500 plants ha^{-1} on 30 May, 2009.

3.4 Crop Management Practices: Fertiliser Application, Weed and Pest Control

NPK 15–15–15 fertiliser was applied on 17 July, 2009 at the rate of 8 g per hill corresponding to 250 kg ha^{-1} while ammonium sulphate fertiliser was applied on 29 July, 2009 at the rate of 4 g per hill corresponding to 125 kg ha^{-1}. Weed control was carried out on 15 July, 2009. The weed control treatments included weed control with a hand hoe, cutlass, weed wiper, knapsack sprayer, and no weed control. Weed control with the weed wiper and knapsack sprayer was effected with Tarzan 480 SL, a systemic herbicide at 480 g glyphosate per litre. Insect pest control was carried out on 17 June, 2009 using a knapsack sprayer and a non-systemic contact insecticide (RAMBO 2.5 EC) containing 25 g of Lambda-cyhalothrin per litre at a rate of 600 mls ha^{-1}.

3.5 Data Collection

3.5.1 Crop Measurements

The data collected included percentage seedling emergence, plant height, stem girth, number of leaves, root length and dry matter yield of *Obaatanpa* maize under different ploughing depth and weed control treatments. Other data collected included soil penetration resistance, dry bulk density, soil moisture content total porosity and air content under different ploughing depth and weed control treatments.

3.5.1.1 Percentage Seedling Emergence

Obaatanpa maize plant population counts were taken daily until emergence was deemed complete. Percentage seedling emergence was calculated by dividing the number of emerged plants counted by the number of seeds planted and expressed as a percentage.

3.5.1.2 Plant Height, Stem Girth and Number of Leaves

Six *Obaatanpa* maize plants were selected per plot at random and tagged for determination of plant height, stem girth, and number of leaves per plant at weekly intervals for 10 weeks starting one week after planting. Plant height was measured using a metre rule. Stem girth was measured using a thread, and a ruler. The numbers of leaves of the six tagged plants per plot were counted at weekly intervals.

3.5.1.3 Root Length and Dry Matter Yield

Six *Obaatanpa* maize root lengths were measured per plot. Root length was measured as the length from the base of the shoot to the tip of the root of each plant using a ruler. The dry matter yields were determined by manually harvesting the six tagged *Obaatanpa* maize plants per plot on 5 September, 2009. The plants were washed and cleaned to remove traces of soil before oven drying them at 70 ^{o}C for 48 hours.

3.5.1.4 Weed Population Density

Weed population density was taken on 2 July, 2009. All above ground weed biomass in one metre square quadrat was harvested from each of the 60 plots. Data was collected at random from each plot. The weed samples were brought to the laboratory and broadleaf weeds were separated from grass weeds. The samples were oven dried at 70 ^{o}C for 48 hours. The dry matter of weed biomass was taken using an electronic balance.

3.5.2 Soil samples

Two sets of soil samples were taken from the 0–15 cm and 15–30 cm layers, and analyzed for their physical and chemical properties. The properties investigated included soil composition in terms of sand, silt, clay, pH, organic carbon, organic matter, total N, exchangeable cations including Ca, Mg, K, and NH_4^+N, and available P. The first set of soil samples was taken prior to starting the experiment on 20 May 2009 to provide a base-line measurement. The second set was taken after harvest on 5 October, 2009.

3.5.2.1 Penetration Resistance

Three sets of soil penetration resistance readings were taken. The first set was taken on 20 May 2009. The second set was taken on 5 August, 2009 while the third set was taken on 5 October, 2009. Soil penetration resistance was measured with a pocket penetrometer. Ten replications were taken at random from each plot resulting in a total of 600 penetrometer readings per given day.

3.5.2.2 Dry Bulk Density

Soil dry bulk density was determined by obtaining undisturbed soil cores of known volume and dividing by the oven dry soil mass by the core volume of the sample. To determine the dry bulk density of the two different layers, undisturbed soil cores 5 cm long and 5 cm in diameter were collected from the mid-point of different layers (0–15 cm and 15–30 cm) with the help of a core sampler. Precautions were taken to avoid compaction inside the core sampler. The collected soil cores were trimmed to the exact volume of the cylinder and oven dried at 105^{o} C for 24 hours. The mass was recorded using an electronic balance. Two core samples were collected at random from each of the 60 plots at the 0–15 cm and 15–30 cm depths on 20 May 2009, 5 August, 2009 and 5 October, 2009 respectively. Soil dry bulk density was calculated by dividing the volume of solids by the total volume of the soil sample.

3.5.2.3 Moisture Content

Two soil samples were randomly taken from each of the 60 plots at the 0–15 cm and 15–30 cm depths, before ploughing (20 May 2009), after planting (5 August 2009) and after harvest (5 October 2009), using a steel core sampler of dimension 5 cm diameter by 5 cm height. Soil moisture content was determined gravimetrically.

3.5.2.4 Air Content

The air content of the soil in the 0–15 cm and 15–30 cm layers was calculated from the values of the total porosity and moisture content.

3.5.2.5 Total Porosity

The total porosity of the soil in the 0–15 cm and 15–30 cm layers was calculated from the values of the dry bulk and particle densities using the following Equation (Chancellor, 1994):

$$Porosity = \left(1 - \frac{\rho_b}{\rho_p}\right)$$

where

ρ_b = Dry bulk density (Mg m^{-3})

ρ_p = Particle density (Mg m^{-3}) = 2.65 Mg m^{-3} (Assumed)

3.6 Statistical analyses

All data were analyzed by two-way analyses of variance using the General Linear factorial Model in MINITAB Statistical Software Release 15 (MINITAB Inc., 2007). The treatment means were compared using least significant differences for the individual factor effects as well as their interactions when there was significant difference between treatments. Treatments were significant at a level of 0.05.

Two sample t tests were performed to determine the effect of ploughing on soil physical and chemical properties before ploughing and after harvesting. The soil properties consisted of sand, silt, clay, pH, organic carbon, organic matter, total N, exchangeable cations including Ca, Mg, K, and NH_4^+N, and available P. The two sample t tests were carried out using the MINITAB Statistical software Release 15 (MINITAB Inc., 2007).

4. RESULTS AND DISCUSSION

4.1 Introduction

The objective of the study was to determine the effect of ploughing depth and weed control treatments on *obaatanpa* maize variety seedling emergence, plant height, stem girth, number of leaves, root length, dry matter yield, and dry matter yield of weeds. The other objective was to determine the effect of ploughing depth and weed control treatments on soil penetration resistance, dry bulk density, moisture content, total porosity and air content. In this chapter, the results of the field study are presented and discussed. The MINITAB Statistical Software Release 15 output dealing with the analyses of the detailed experimental results are given in Appendix 2.

4.2 Soil properties before ploughing and after harvest

The physical and chemical properties of the soil at the experimental site before ploughing and after harvest are shown in Table 4.1. The soil texture for the 0–15 cm layer as well as that of the 15–30 cm layer before ploughing was sandy loam. The textural class for the 0–15 cm layer after harvest was also sandy loam. However, the textural class for the 15–30 cm layer after harvest was sandy clay loam. The soil at the site was identified as Ferric Acrisol (FAO, 1998) (Paleustult in USDA Classification).

Mean sand, silt and clay contents for both 0–15 cm and 15–30 cm soil layers were statistically similar before ploughing and after harvesting of the *obaatanpa* maize crop. Organic carbon and organic matter at the 0–15 cm soil layer before ploughing and after harvest were not different. On the other hand, organic carbon and organic matter were statistically significantly different before ploughing compared with that after harvesting in the 15–30 cm soil depth layer. Soil organic carbon was significantly reduced from 1.08% to

0.53% by ploughing. Likewise, soil organic matter was significantly reduced from 1.87% before ploughing to 0.91% after harvesting (Table 4.1). In the 0–15 cm soil layer, pH was increased from 5.27 before ploughing to 5.43 after harvesting although the difference was not significant. However, in the 15–30 cm soil layer, pH was significantly increased from 5.21 before ploughing to 5.38 after harvesting. Ploughing therefore reduced the acidity of the soil. Maize requires acid soil of pH between 5.0 and 5.5.

Table 4.1: Properties of the soil before ploughing and after harvest

	Before ploughing		After harvesting	
	Soil layer (cm)		Soil layer (cm)	
Soil properties	0–15	15–30	0–15	15–30
Sand (%)	80.4	80.4	77.1	71.9
Silt (%)	6.9	5.9	6.5	5.9
Clay (%)	12.8	13.7	16.3	22.2
Organic carbon (%)	1.20	1.08	0.91	0.53
Organic matter (%)	2.07	1.87	1.57	0.91
pH	5.27	5.21	5.43	5.38
Total N (%)	0.20	0.18	0.18	0.14
Ca (cmol kg^{-1})	5.20	4.50	3.87	3.47
Mg (cmol kg^{-1})	1.40	2.00	2.33	1.07
K (cmol kg^{-1})	0.13	0.09	0.08	0.05
NH_4^+N (cmol kg^{-1})	4.90	3.80	5.45	2.91
Available P (mg kg^{-1})	15.92	12.36	15.11	11.82

Mean soil total N, Ca, K and available P for both 0–15 cm and 15–30 cm soil layers were statistically similar before ploughing and after harvesting of the *obaatanpa* maize crop. Mg in the 0–15 cm soil layer increased from 1.40 cmol kg^{-1} before ploughing to 2.33 cmol kg^{-1} after harvesting although the difference was not statistically significant. Conversely, Mg in the 15–30 cm soil layer decreased from 2.00 before ploughing to 1.07 after harvesting although the difference was not statistically significant. In the 0–15 cm soil layer, NH_4^+N was increased from 4.90 cmol kg^{-1} before ploughing to 5.45 cmol kg^{-1} after harvesting although the difference was not significant. However, in the 15–30 cm soil layer, NH_4^+N was significantly decreased from 3.80 cmol kg^{-1} before ploughing to 2.91 cmol kg^{-1} after harvesting.

4.3 Maize growth and yield

4.3.1 Effect of ploughing depth on seedling emergence

Fig. 4.1 shows the effect of ploughing depth on *obaatanpa* maize variety seedling emergence over a period of 19 days after planting. Initially there was statistical significant difference in seedling emergence between the different depths of disc ploughing. However, after the first four days of emergence, there was no statistical significant difference in seedling emergence between the ploughing depth treatments. Overall, the highest seedling emergence of 86.13% was found in the 20–25 cm ploughing depth plots while the lowest seedling emergence of 84.53% was found in the 0 cm (No-Tillage) plots.

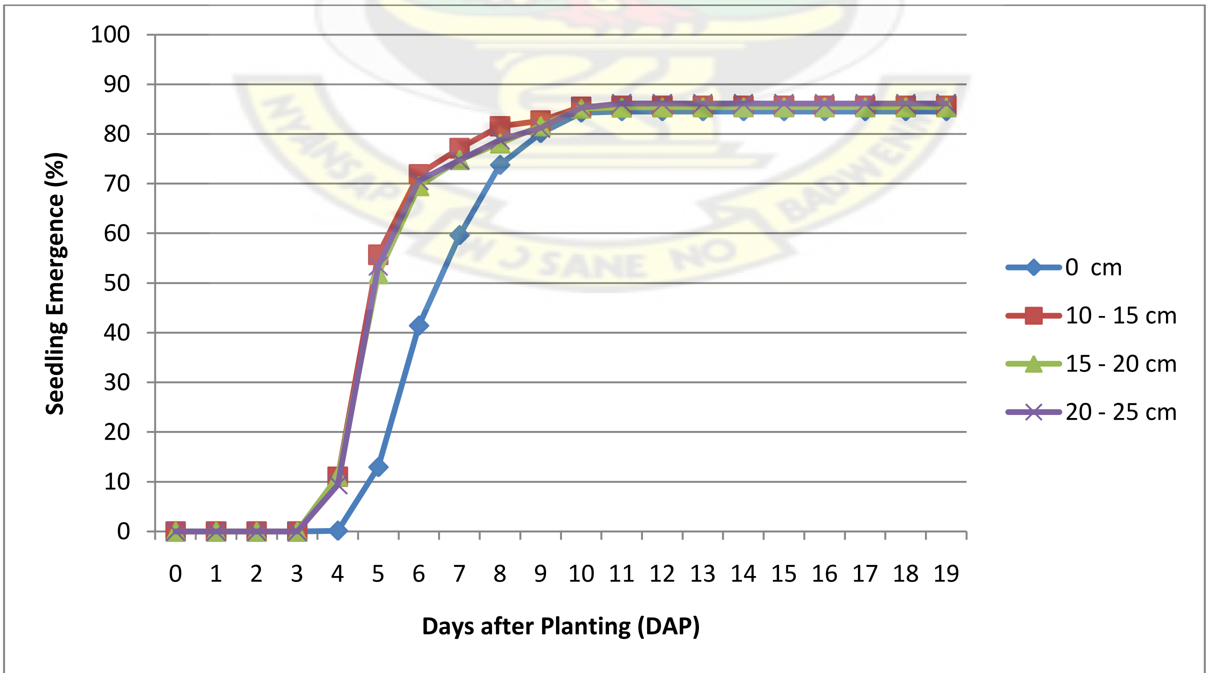

Fig. 4.1: Effect of ploughing depth on seedling emergence

4.3.2 Effect of ploughing depth and weed control treatments on plant height

4.3.2.1 Effect of ploughing depth on plant height

The effect of ploughing depth on *obaatanpa* maize plant height is presented in Fig. 4.2. Ploughing depth had statistical significant effect on plant height over the period of the experiment. The tallest plant height (180.50 cm) was located in the 15–20 cm ploughing depth plots ten weeks after planting. This was followed by the 20–25 cm (179.78 cm) and 10–15 cm (173.24 cm) ploughing depth treatments. The shortest plant (104.98 cm) was found in the 0 cm ploughing depth (No Till) plots which was significantly smaller than that of the other ploughing depth treatments.

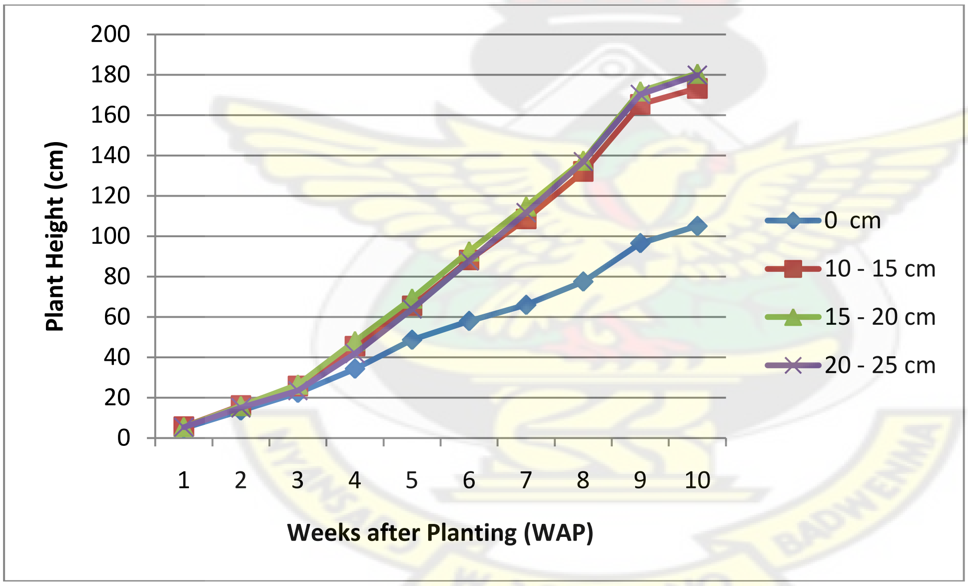

Fig. 4.2: Effect of ploughing depth on plant height

4.3.2.2 Effect of weed control treatment on plant height

Fig. 4.3 gives the effect of weed control treatment on *obaatanpa* maize plant height. Unlike ploughing depth, weed control treatment did not have statistical significant difference in plant height between the different weed control treatments. However, the tallest plant height

(170.53 cm) was found in the cutlass weed control plots while the shortest plant (143.04 cm) was in the knapsack sprayer plots.

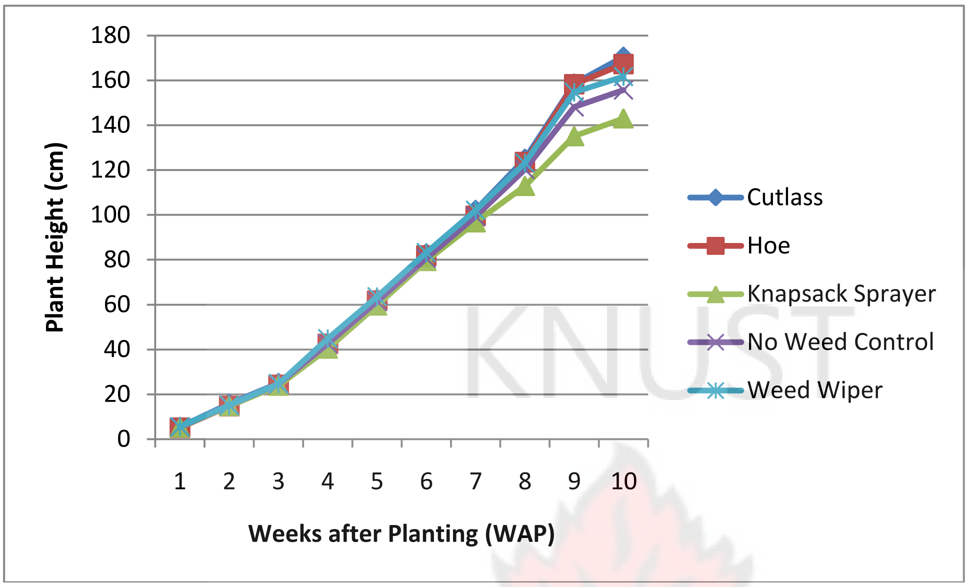

Fig. 4.3: Effect of weed control treatment on plant height

4.3.3 Effect of ploughing depth and weed control treatments on stem girth

4.3.3.1 Effect of ploughing depth on stem girth

Fig. 4.4 illustrates the effect of ploughing depth on stem girth on the first ten weeks of the experiment. Ploughing depth treatments had significant effect on *obaatanpa* stem girth. Maize stem girth at the 10–15 cm, 15–20 cm and 20–25 cm ploughing depths was significantly greater than that of the 0 cm ploughing depth. There was no significant difference in stem girth between the 10–15 cm, 15–20 cm and 20–25 cm ploughing depth treatments. Ten weeks after planting, the biggest stem girth (57.53 mm) was found in the 20–25 cm ploughing depth plots while the smallest stem girth (36.49 mm) was located in the 0 cm ploughing depth plots.

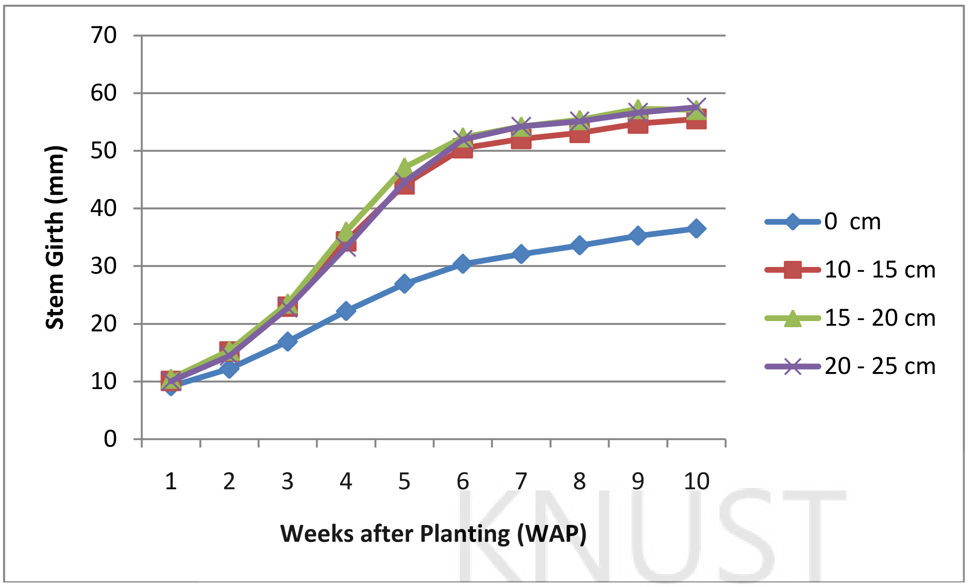

Fig. 4.4: Effect of ploughing depth on stem girth

4.3.3.2 Effect of weed control treatment on stem girth

Fig. 4.5 presents the effect of weed control treatment on stem girth over the first ten weeks of the experiment. Statistical analysis of the data showed no significant difference in plant stem girth between the different weed control treatments. Ten weeks after planting, the biggest stem girth (52.42 mm) was obtained from the hoe weed control plots while the smallest stem girth (49.50 mm) was produced in the knapsack sprayer plots.

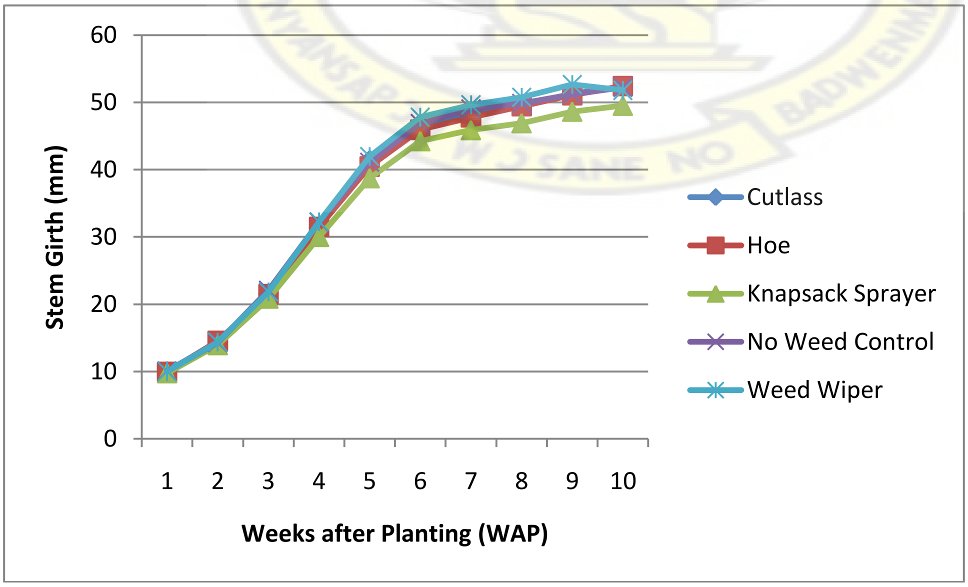

Fig. 4.5: Effect of weed control treatment on stem girth

4.3.4 Effect of ploughing depth and weed control treatments on number of leaves

4.3.4.1 Effect of ploughing depth on number of leaves per plant

The number of leaves (Fig. 4.6) was significantly higher in the 10–15 cm, 15–20 cm, and 20–25 cm ploughing depths compared with the 0 cm ploughing depth over the period of the experiment. The number of leaves in the 10–15 cm, 15–20 cm, and 20–25 cm ploughing depths were statistically similar. Ten weeks after planting, the highest number of leaves (17.71) was located in the 10–15 cm ploughing depth plots while the lowest number of leaves (14.87) was found in the 0 cm ploughing depth plots.

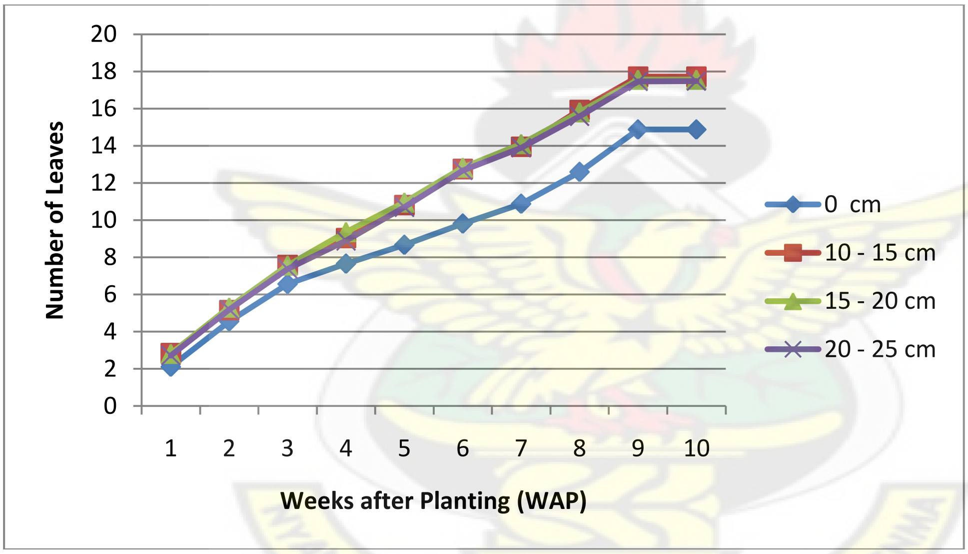

Fig. 4.6: Effect of ploughing depth on number of leaves per plant

4.3.4.2 Effect of weed control treatment on number of leaves

Fig. 4.7 shows the trend in number of leaves under the different weed control treatments over the period of the experiment. There was statistical significant difference in the number of leaves between the weed control treatments. Weed control under the hoe presented the highest number of leaves (17.33). Weed control with the knapsack sprayer gave the lowest number of leaves (16.20).

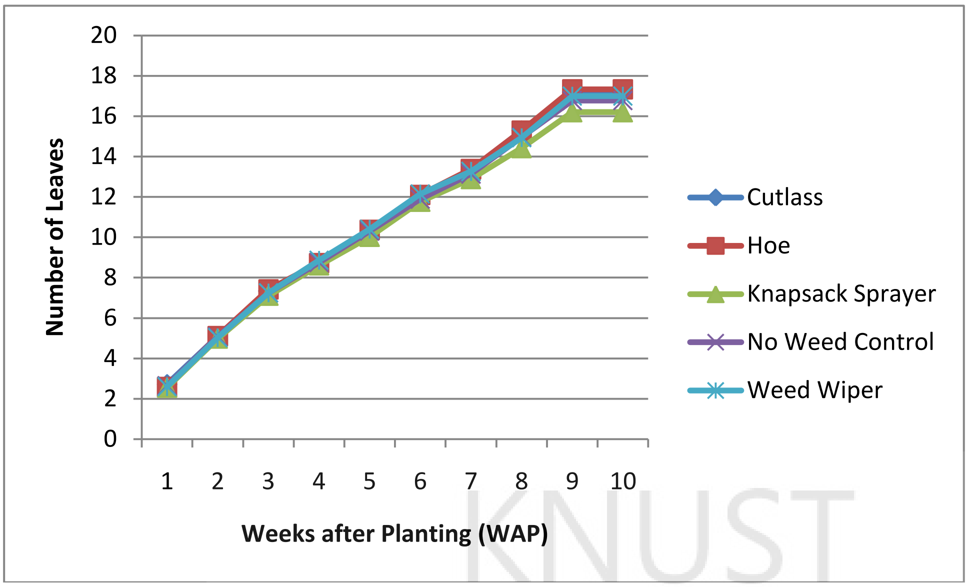

Fig. 4.7: Effect of weed control treatment on number of leaves

4.3.5 Effect of ploughing depth on root length and dry matter yield

Table 4.2 portrays results of the effect of ploughing depth on root length and dry matter yield at 98 days after planting (DAP). Different ploughing depths statistically significantly affected the root length and dry matter yield of *obaatanpa* maize variety. Ploughing at the 20–25 cm depth produced the longest root length (46.34 cm) and highest dry matter yield (8155 kg ha^{-1}). This may be attributed to the greater loosening of the impeding soil layer by the deep ploughing depth treatment. The 0 cm ploughing depth presented the shortest root length (27.72 cm) and the lowest dry matter yield (2573 kg ha^{-1}). These results agree with that presented by Rashid and Keshavarzpour (2008). The root is the main organ of the plant which has to make contact with the soil to absorb nutrients and water but the quantum and rate of water and nutrient uptake by the plants depend mainly on the development of the root system in spread, depth and density particularly under conditions of dryland agriculture (Nitant and Singh, 1995).

Table 4.2: Effect of ploughing depth on root length and dry matter yield at 98 DAP

Ploughing Depth	Root Length (cm)	Dry Matter Yield (kg ha^{-1})
0 cm	27.72	2573
10–15 cm	45.85	5743
15–20 cm	43.74	6654
20–25 cm	46.34	8155
Mean	40.91	5781
LSD (p<0.05)	2.48	1375

4.3.6 Effect of weed control treatment on root length and dry matter yield

Weed control treatment did not affect *obaatanpa* root length and dry matter yield over the period of the experiment (Table 4.3). Although there was no statistical significant difference, weed control with the weed wiper resulted in the longest root length (41.85 cm) and the highest dry matter yield (6348 kg ha^{-1}). The shortest root length was observed in the knapsack sprayer plots (39.62 cm) with dry matter yield of 6315 kg ha^{-1}. The no weed control treatment produced root length of 40.26 cm and the smallest dry matter yield of 4348 kg ha^{-1}. These results emphasize the need for weed control in the production of maize.

Table 4.3: Effect of weed control treatment on root length and dry matter yield at 98 DAP

Ploughing Depth	Root Length (cm)	Dry Matter Yield (kg ha^{-1})
Cutlass	41.24	5790
Hoe	41.62	6107
Knapsack Sprayer	39.62	6315
No Weed Control	40.26	4348
Weed Wiper	41.85	6348
Mean	40.92	5782
LSD (p<0.05)	NS	NS

4.3.7 Interaction effect of ploughing depth and weed control treatments on maize performance

The interaction effect of ploughing depth and weed control treatments on maize plant height, stem girth, and number of leaves at 70 DAP are presented in Table 4.4. There was no statistical significant difference in interaction effect on plant height, stem girth and number of leaves. However, the tallest plant height (198.42 cm) and the biggest stem girth (62.70 mm) were found in the 15–20 cm x No Weed control treatment combination while the shortest plant height (87.51 cm) and the smallest stem girth (32.83 mm) were located in the 0 cm (No-Tillage) x No Weed control treatment combination. The highest number of leaves (18.17) was observed in the 10–15 cm x Weed Wiper and 15–20 cm x No Weed Control plots. On the other hand, the lowest number of leaves per plant was located in the 0 cm x Knapsack Sprayer plots.

Table 4.4: Interaction effect of ploughing depth and weed control treatments on maize plant height, stem girth, and number of leaves at 70 DAP

Ploughing Depth x Weed Control	Plant Height (cm)	Stem Girth (mm)	Number of Leaves
0 cm x Cutlass	116.40	36.07	15.22
0 cm x Hoe	115.14	42.00	16.72
0 cm x Knapsack Sprayer	89.17	34.60	13.56
0 cm x No Weed Control	87.51	32.83	13.89
0 cm x Weed Wiper	116.69	36.93	14.94
10–15 cm x Cutlass	188.12	57.23	17.89
10–15 cm x Hoe	192.47	54.80	17.61
10–15 cm x Knapsack Sprayer	151.57	54.30	17.28
10–15 cm x No Weed Control	158.14	54.23	17.61
10–15 cm x Weed Wiper	175.93	57.00	18.17
15–20 cm x Cutlass	186.51	57.30	18.05
15–20 cm x Hoe	192.09	59.37	17.50
15–20 cm x Knapsack Sprayer	160.18	54.87	16.89
15–20 cm x No Weed Control	198.42	62.73	18.17
15–20 cm x Weed Wiper	165.29	51.27	17.17
20–25 cm x Cutlass	191.11	58.80	17.72
20–25 cm x Hoe	169.23	53.50	17.50
20–25 cm x Knapsack Sprayer	171.23	54.23	17.06
20–25 cm x No Weed Control	178.65	59.17	17.39
20–25 cm x Weed Wiper	188.67	61.93	17.72
Mean	159.63	51.66	16.90
LSD ($p < 0.05$)	NS	NS	NS

NS = Not significant

Table 4.5 displays the interaction effect of ploughing depth and weed control treatments on root length and dry matter yield at 98 days after planting. *Obaatanpa* maize root length and dry matter yield were not statistically significantly affected by the interaction between ploughing depth and weed control treatments. The results show that the longest root length (47.99 cm) was obtained from the interaction between the 20–25 cm ploughing depth and the Weed Wiper weed control treatments. The shortest root length (25.64 cm) and the smallest dry matter yield (1541 kg ha^{-1}) was observed in the 0cm x No Weed Control treatment combination. The highest dry matter yield (10020 kg ha^{-1}) was produced by the 20–25 cm x Knapsack Sprayer plots.

Table 4.5: Interaction effect of ploughing depth and weed control treatments on maize root length and dry matter yield at 98 DAP

Ploughing Depth x Weed Control	Root Length (cm)	Dry Matter Yield (kg ha^{-1})
0 cm x Cutlass	29.74	3114
0 cm x Hoe	29.64	2944
0 cm x Knapsack Sprayer	26.92	2467
0 cm x No Weed Control	25.64	1541
0 cm x Weed Wiper	26.65	2799
10–15 cm x Cutlass	47.62	5984
10–15 cm x Hoe	47.04	6638
10–15 cm x Knapsack Sprayer	41.19	4836
10–15 cm x No Weed Control	46.08	3915
10–15 cm Weed Wiper	47.33	7341
15–20 cm x Cutlass	43.10	6707
15–20 cm x Hoe	43.97	6597
15–20 cm x Knapsack Sprayer	43.35	8067
15–20 cm x No Weed Control	42.87	5501
15–20 cm x Weed Wiper	45.42	6399
20–25 cm x Cutlass	44.49	7355
20–25 cm x Hoe	45.81	8249
20–25 cm x Knapsack Sprayer	47.00	10020
20–25 cm x No Weed Control	46.43	6433
20–25 cm x Weed Wiper	47.99	8720
Mean	40.91	5,781
LSD ($p < 0.05$)	NS	NS

NS = Not significant

4.4 Type of weeds identified and dry matter yield of weeds

Maize is a heavy user of water and so it is usually grown during the major or minor crop growing seasons. The conditions created during these seasons are favourable for the growth of a wide variety of weeds. Table 4.6 presents the major weed species and their associated family identified at the field. Overall, there were more grasses than broadleaf.

Table 4.6: Weeds present at the experimental site

No.	Species	Family
1.	*Acanthospernum hispidum*	Asteraceae
2.	*Ageratum conyzoides*	Asteraceae
3.	*Boerhavia diffusa*	Myctaginaceae
4.	*Calopogonium*	Fabaceae
5.	*Commelina benghalensis*	Commelinaceae
6.	Cowpea	Vigna unguculata
7.	*Cyperus rotundus*	Cyperaceae
8.	*Digitaria horizontalis*	Poaceae
9.	*Euphorbia heterophylla*	Euphorbiaceae
10.	*Laportea aestuans*	Urticaceae
11.	*Mimosa pudica*	Mimosaceae
12.	*Mimosa invisa*	Leguminosae-mimosoideae
13.	*Paspalum serobiculatum*	Poaceae
14.	*Phyllanthus amarus*	Euphorbiaceae
15.	*Sorghum arundinaceum*	Poaceae
16.	*Spigelia anthelmia*	Loganiaceae
17.	*Synedrella nodiflon*	Asteraceae

Table 4.7 displays details of the weed dry matter yield of the grasses and broadleaf weeds. Analysis of variance showed significant effect of ploughing depth on weed dry matter yield. The highest weed dry matter yield was 693.23 kg ha^{-1} for grasses and 648.89 kg ha^{-1} for broadleaf. Significant effect was in the order 0 cm > 10–15 cm, 15–20 cm, 20–25 cm for both grasses and broadleaf There was no statistical significant difference in weed dry matter yield among the 10–15 cm, 15–20 cm, and 20–25 cm ploughing depth treatments. Overall, weed dry matter decreased with increasing depth of ploughing suggesting that the deeper the depth of ploughing the better the weed control. The lowest weed dry matter yield was 134.87kg ha^{-1} for the deepest ploughing depth (20–25 cm) while the highest weed dry matter yield was 671.06 kg ha^{-1} for the 0 cm (No Tillage) treatment.

Table 4.7: Effect of ploughing depth on weed dry matter yield (kg ha^{-1}) at 33 DAP

Ploughing Depth	Grasses	Broadleaf	Grasses and Broadleaf
0 cm	693.23	648.89	671.06
10–15 cm	260.31	61.32	160.82
15–20 cm	194.45	102.41	148.43
20–25 cm	198.70	71.03	134.87
Mean	337	221	279
LSD (p<0.05)	156.21	114.14	

4.5 Soil properties

4.5.1 Effect of ploughing depth and weed control treatments on soil penetration resistance

4.5.1.1 Effect of ploughing depth on soil penetration resistance

Table 4.8 shows the mean values of soil penetration resistance for each ploughing depth treatment before ploughing (20 May 2009), after planting (5 August 2009) and after harvest (5 October 2009). Ploughing depth treatments did not result in a significant difference in soil penetration resistance before ploughing and after planting (Table 4.8). However, after harvest, there was statistical significant difference in soil penetration resistance between the different ploughing depth treatments. Ploughing at 0 cm (No Tillage) produced penetration resistance (343 kPa) significantly higher than that of the other ploughing depth treatments. There was however, no significant difference in penetration resistance between the 10–15 cm, 15–20 cm and 20–25 cm ploughing depth treatments.

Table 4.8: Effect of ploughing depth on soil penetration resistance (kPa)

Ploughing depth	20 May 2009	5 August 2009	5 October 2009
0 cm	579	425	343
10–15 cm	569	404	304
15–20 cm	561	391	309
20–25 cm	556	404	317
Mean	566	406	318
LSD (p<0.05)	NS	NS	15.7

NS = Not significant

4.5.1.2 Effect of weed control treatment on soil penetration resistance

The penetration resistance in the different weed control treatment plots is shown in Table 4.9. Statistically, there was no significant difference in soil penetration resistance before ploughing (20 May 2009), after planting (5 August 2009) and after harvest (5 October 2009) between the weed control treatments.

Table 4.9: Effect of weed control treatment on soil penetration resistance (kPa)

Weed Control Treatment	20 May 2009	5 August 2009	5 October 2009
Cutlass	568	412	320
Hoe	568	417	325
Knapsack Sprayer	569	397	314
No Weed Control	555	409	306
Weed Wiper	571	394	326
Mean	566	406	318
LSD (p<0.05)	NS	NS	NS

4.5.2 Interaction effect of ploughing depth and weed control treatments on soil penetration resistance

Table 4.10 displays the interaction effect of ploughing depth and weed control treatment on soil penetration resistance. The results demonstrate that there was no significant difference in interaction effect in soil penetration resistance among the treatments before ploughing (20 May 2009), after planting (5 August 2009) and after harvest (5 October 2009) between the weed control treatments.

Table 4.10: Interaction effect of ploughing depth and weed control treatments on soil penetration resistance (kPa)

Ploughing Depth x Weed Control	20 May 2009	5 August 2009	5 October 2009
0 cm x Cutlass	571.4	423.1	337.6
0 cm x Hoe	578.0	434.5	354.4
0 cm x Knapsack Sprayer	575.5	422.5	341.7
0 cm x No Weed Control	587.0	429.7	337.6
0 cm x Weed Wiper	584.5	414.9	345.2
10–15 cm x Cutlass	593.5	401.4	294.5
10–15 cm x Hoe	578.8	420.2	301.1
10–15 cm x Knapsack Sprayer	578.0	418.2	293.6
10–15 cm x No Weed Control	545.7	393.8	308.4
10–15 cm Weed Wiper	548.5	387.1	319.8
15–20 cm x Cutlass	549.0	431.2	308.2
15–20 cm x Hoe	565.7	378.1	317.8
15–20 cm x Knapsack Sprayer	564.9	367.1	313.5
15–20 cm x No Weed Control	538.3	398.3	287.7
15–20 cm x Weed Wiper	584.9	377.7	318.2
20–25 cm x Cutlass	557.1	392.9	338.4
20–25 cm x Hoe	549.8	434.7	325.9
20–25 cm x Knapsack Sprayer	557.5	381.0	308.2
20–25 cm x No Weed Control	549.4	415.5	291.1
20–25 cm x Weed Wiper	566.9	395.3	320.0
Mean	566.2	405.9	318.1
LSD ($p < 0.05$)	NS	NS	NS

NS = Not significant

4.5.3 Effect of ploughing depth and weed control treatments on dry bulk density

4.5.3.1 Effect of ploughing depth on dry bulk density

The dry bulk density in the different ploughing depth treatments for the 0–15 cm and 15–30 cm depth layers before ploughing (20 May 2009), after planting (5 August 2009) and after harvest (5 October 2009) is presented in Table 4.11. Soil dry bulk density was not significantly affected by ploughing depth treatment except for 5 August 2009 when there was significant difference in both the 0–15 cm and 15–30 cm depth layers. Dry bulk density was lowest in the 20–25 cm ploughing depth plots for both the 0–15 cm and 15–30 cm depth layers on 5 August 2009.

Table 4.11: Effect of ploughing depth on dry bulk density (Mg m^{-3})

	20 May 2009		5 August 2009		5 October 2009	
Ploughing Depth	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer
0 cm	1.36	1.37	1.40	1.41	1.37	1.33
10–15 cm	1.37	1.35	1.41	1.41	1.30	1.33
15–20 cm	1.37	1.30	1.40	1.42	1.37	1.39
20–25 cm	1.33	1.28	1.31	1.27	1.37	1.40
Mean	1.36	1.33	1.38	1.38	1.35	1.36
LSD ($p<0.05$)	NS	NS	0.052	0.057	NS	NS

NS = Not significant

4.5.3.2 Effect of weed control treatment on dry bulk density

Table 4.12 gives the results of the effect of weed control treatment on soil dry bulk density. Weed control treatments did not significantly affect dry bulk density in the 0–15 cm and 15–30 cm depth layers before ploughing (20 May 2009), after planting (5 August 2009) and after harvest (5 October 2009).

Table 4.12: Effect of weed control treatment on dry bulk density (Mg m^{-3})

	20 May 2009		5 August 2009		5 October 2009	
Weed Control Treatment	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer
Cutlass	1.37	1.34	1.36	1.34	1.33	1.33
Hoe	1.33	1.31	1.38	1.41	1.39	1.40
Knapsack Sprayer	1.37	1.32	1.42	1.41	1.38	1.38
No Weed Control	1.37	1.34	1.36	1.33	1.32	1.35
Weed Wiper	1.37	1.32	1.41	1.39	1.34	1.34
Mean	1.36	1.32	1.38	1.38	1.35	1.36
LSD ($p<0.05$)	NS	NS	NS	NS	NS	NS

NS = Not significant

4.5.4 Effect of ploughing depth and weed control treatments on soil moisture content

4.5.4.1 Effect of ploughing depth on soil moisture content

Table 4.13 displays the mean values of soil moisture content as affected by depth of ploughing before ploughing (20 May 2009), after planting (5 August 2009) and after harvest (5 October 2009). Ploughing at 20–25 cm depth produced the highest moisture content in comparison with the other ploughing depth treatments in both the 0–15 cm and 15–30 cm layers. It can be seen that ploughing depth treatment did not have significant effect on soil moisture content before ploughing and after planting. However, soil moisture content in both the 0–15 cm and 15–30 cm layers was significantly influenced by the depth of ploughing after harvesting the *obaatanpa* maize crop. Ploughing at 20–25 cm depth significantly increased gravimetric soil moisture content in comparison with the 0 cm depth (No Tillage) treatment in the 0–15 cm layer. There was nonetheless, no significant difference in moisture content between the 10–15 cm, 15–20 cm and 20–25 cm depth treatments. Similarly, ploughing at 20–25 cm depth had significant effect on moisture content compared with the other ploughing depth treatments. The 15–20 cm ploughing also produced moisture content significantly greater than that of the 10–15 cm ploughing depth. There was no significant difference in moisture content in the 15–30 cm layer between the 0 cm and 10–15 cm ploughing depth treatments. These results are in agreement with that of Khurshid *et al*. (2006).

Table 4.13: Effect of ploughing depth on soil moisture content (%)

	20 May 2009		5 August 2009		5 October 2009	
Ploughing Depth	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer
0 cm	10.21	9.34	11.57	11.75	11.94	12.84
10–15 cm	9.75	9.52	12.31	11.25	13.38	12.11
15–20 cm	9.81	10.04	11.71	10.83	13.26	13.45
20–25 cm	10.42	10.31	12.55	12.35	13.56	14.51
Mean	10.05	9.80	12.04	11.55	13.04	13.23
LSD ($p<0.05$)	NS	NS	NS	NS	1.01	0.97

4.5.4.2 Effect of weed control treatment on soil moisture content

The mean values of soil moisture content as influenced by weed control treatment before ploughing (20 May 2009), after planting (5 August 2009) and after harvest (5 October 2009) are presented in Table 4.14. Soil moisture content values were not significantly different due to weed control treatment, except in the 15–30 cm layer on 5 August 2009 (Table 4.14). Throughout the study period, the highest moisture content was recorded in the knapsack sprayer plots. Similarly, the lowest soil moisture content was observed in the no weed control plots (except for 20 May 2009 in the 0–15 cm layer). This may be attributed to the weeds robbing soil of moisture in competition with the *obaatanpa* maize plant. Soil moisture content in the 15–30 cm layer on 5 August 2009 was significantly higher in the knapsack sprayer plots compared with that of the other weed control treatment plots.

Table 4.14: Effect of weed control treatment on soil moisture content (%)

	20 May 2009		5 August 2009		5 October 2009	
Weed control treatment	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer
Cutlass	10.150	9.715	12.32	11.787	13.36	13.04
Hoe	9.637	10.002	11.57	10.973	12.87	13.42
Knapsack Sprayer	10.746	10.068	12.71	12.799	13.86	13.95
No Weed Control	9.748	9.707	11.40	10.407	12.38	12.21
Weed Wiper	9.958	9.515	12.17	11.747	12.71	13.53
Mean	10.048	9.801	12.03	11.543	13.04	13.23
LSD ($p<0.05$)	NS	NS	NS	0.99	NS	NS

4.5.5 Effect of ploughing depth and weed control treatments on total porosity

4.5.5.1 Effect of ploughing depth on total porosity

Over the course of the study, ploughing depth did not significantly affect total porosity for all sampling dates except for 5 August 2009 in the 15–30 cm layer (Table 4.15). On 5 August 2009 the 20–25 cm ploughing depth treatment in the 15–30 cm layer produced total soil porosity significantly greater than that of the other ploughing depth treatments. Between 20 May 2009 and 5 August 2009 the highest total soil porosity was located in the 20–25 cm ploughing depth plots.

Table 4.15: Effect of ploughing depth on total porosity (%)

	20 May 2009		5 August 2009		5 October 2009	
Ploughing depth	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer
0 cm	49.00	48.73	47.40	47.07	48.93	50.20
10–15 cm	48.47	49.47	50.20	47.33	51.07	50.07
15–20 cm	48.53	51.33	47.20	46.87	48.67	47.87
20–25 cm	49.93	52.13	50.93	52.07	48.47	47.60
Mean	48.98	50.42	48.93	48.34	49.29	48.94
LSD(p<0.05)	NS	NS	NS	2.26	NS	NS

4.5.5.2 Effect of weed control treatment on total porosity

Table 4.16 shows the mean values of total porosity as affected by weed control treatments over the study period. There was no statistical significant difference in total porosity between the different weed control treatments.

Table 4.16: Effect of weed control treatment on total porosity (%)

	20 May 2009		5 August 2009		5 October 2009	
Weed Control Treatment	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer
Cutlass	48.58	50.00	49.17	49.42	50.08	50.08
Hoe	50.33	51.00	48.42	47.25	48.08	47.42
Knapsack Sprayer	48.67	50.67	46.58	47.08	48.08	48.00
No Weed Control	48.67	49.75	49.17	50.08	50.50	49.42
Weed Wiper	48.67	50.67	51.33	47.83	49.67	49.75
Mean	48.98	50.42	48.93	48.33	49.28	48.93
LSD (p<0.05)	NS	NS	NS	NS	NS	NS

4.5.6 Effect of ploughing depth and weed control treatments on air content

4.5.6.1 Effect of ploughing depth on air content

Soil air is important for the aeration of roots and increasing crop production levels. Table 4.17 presents the mean values of the results pertaining to the effect of ploughing depth on air content between before ploughing (20 May 2009), after planting (5 August 2009) and after harvest (5 October 2009) in both the 0–15 cm and 15–30 cm layers. As can be seen, the 20–25 cm ploughing depth presented the highest air content between 20 May 2009 and 5 August 2009. However, the 15–20 cm ploughing depth gave the highest air content after harvest (5 October 2009). Ploughing depth treatments did not significantly influence soil air content.

Table 4.17: Effect of ploughing depth on air content (%)

	20 May 2009		5 August 2009		5 October 2009	
Ploughing depth	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer
0 cm	34.89	36.17	30.91	30.40	32.48	33.14
10–15 cm	34.82	36.31	29.30	31.27	37.44	33.92
15–20 cm	35.01	38.23	30.50	31.12	30.01	28.96
20–25 cm	35.85	38.68	34.18	35.41	29.06	26.93
Mean	35.14	37.35	31.22	32.05	32.25	30.74
LSD (p<0.05)	NS	NS	NS	NS	NS	NS

4.5.6.2 Effect of weed control treatment on air content

The result of the mean values of air content as influenced by weed control treatments over the course of the study in the 0–15 cm and 15–30 cm layers is depicted in Table 4.18. Mean air content values ranged between 37.80 and 27.46. Analysis of variance showed no significant effect of weed control on air content except for that in the 15–30 cm layer on 5 August 2009. On this date, the no weed control produced soil air content significantly greater than that of all the weed control treatments except for the cutlass. Between 5 August 2009 and 5 October 2009, the no weed control treatment consistently produced the highest air content in both the 0–15 cm and 15–30 cm layers.

Table 4.18: Effect of weed control treatment on air content (%)

	20 May 2009		5 August 2009		5 October 2009	
Weed Control Treatment	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer	0–15 cm Layer	15–30 cm Layer
Cutlass	34.61	36.85	32.19	33.88	32.04	32.47
Hoe	37.23	37.68	32.14	31.58	29.95	28.57
Knapsack Sprayer	33.80	37.80	28.56	27.46	33.76	28.65
No Weed Control	35.13	36.70	33.47	36.13	33.98	32.65
Weed Wiper	34.96	37.71	29.73	31.21	31.51	31.36
Mean	35.15	37.35	31.22	32.05	32.25	30.74
LSD (p<0.05)	NS	NS	NS	3.35	NS	NS

4.5.7 Interaction effect of ploughing depth and weed control treatments on soil properties in the 0–15 cm layer on 20 May, 2009

The interaction effect of ploughing depth and weed control treatments on dry bulk density, moisture content, total porosity and air content in the 0–15 cm layer before ploughing (20 May, 2009) is presented in Table 4.19. The analysis of variance test showed that there was no significant difference in dry bulk density, moisture content, total porosity and air content in the 0–15 cm layer. The maximum dry bulk density (1.41 Mg m^{-3}) was located in the 10–15 cm x Cutlass, 10–15 cm x Hoe, and 15–20 cm x Cutlass plots while the minimum dry bulk density (1.28 Mg m^{-3}) was found in the 15–20 cm x Hoe plot. In the case of moisture content, the maximum soil moisture content (11.34 %) was observed in the 15–20 cm x Knapsack Sprayer plot while the minimum moisture content (8.75 %) was found in the 10–15 cm x Hoe plot. The maximum total porosity (52.33 %) was located in the 15–20 cm x Hoe plot while the minimum total porosity (47 %) was observed in the 15–20 cm x Cutlass plot. The maximum air content (39.44 %) was recorded in the 15–20 cm x Hoe plot while the minimum moisture content (31.99 %) was located in the 20–25 cm x Knapsack Sprayer plot.

Table 4.19: Interaction effect of ploughing depth and weed control on dry bulk density, moisture content, total porosity and air content in the 0–15 cm layer on 20 May, 2009

Ploughing Depth x Weed Control	Dry Bulk Density ($Mg\ m^{-3}$)	Moisture Content (%)	Total Porosity (%)	Air Content (%)
0 cm x Cutlass	1.38	11.18	48.00	32.96
0 cm x Hoe	1.34	9.89	50.00	36.54
0 cm x Knapsack Sprayer	1.34	10.27	50.00	36.04
0 cm x No Weed Control	1.38	10.12	48.33	34.07
0 cm x Weed Wiper	1.38	9.61	48.67	34.86
10–15 cm x Cutlass	1.41	9.24	47.33	33.87
10–15 cm x Hoe	1.41	8.75	47.33	34.67
10–15 cm x Knapsack Sprayer	1.37	10.11	48.33	34.43
10–15 cm x No Weed Control	1.35	9.43	49.33	36.49
10–15 cm x Weed Wiper	1.33	11.22	50.00	34.66
15–20 cm x Cutlass	1.41	9.48	47.00	33.51
15–20 cm x Hoe	1.28	9.59	52.33	39.44
15–20 cm x Knapsack Sprayer	1.38	11.34	48.67	32.72
15–20 cm x No Weed Control	1.40	9.24	47.33	34.45
15–20 cm x Weed Wiper	1.39	9.38	47.33	34.93
20–25 cm x Cutlass	1.28	10.70	52.00	38.10
20–25 cm x Hoe	1.29	10.32	51.67	38.26
20–25 cm x Knapsack Sprayer	1.39	11.26	47.67	31.99
20–25 cm x No Weed Control	1.35	10.20	49.67	35.51
20–25 cm x Weed Wiper	1.36	9.62	48.67	35.40
Mean	1.36	10.05	48.98	35.15
LSD ($p < 0.05$)	NS	NS	NS	NS

4.5.8 Interaction effect of ploughing depth and weed control treatments on soil properties in the 0–15 cm layer on 5 August, 2009

The analysis of variance showed no statistical significant difference in dry bulk density, moisture content, total porosity and air content between the different ploughing depth and weed control treatments in the 0–15 cm layer on 5 August, 2009 (Table 4.20). The highest value of dry bulk density was 1.46 Mg m^{-3} in the 0 cm x Weed Wiper plot while the lowest value was 1.27 Mg m^{-3} in the 20–25 cm x No Weed Control plot. The highest value of moisture content was 14.14 % in the 10–15 cm x Knapsack Sprayer plot while the lowest value was 10.48 % in the 10–15 cm x Hoe plot. The maximum total porosity (61.67 %) was located in the 10–15 cm x Weed Wiper plot while the minimum total porosity (45.33 %) was observed in the 0 cm x Weed Wiper and 10–15 cm x No Weed Control plot. The highest value of air content was 37.10 % in the 20–25 cm x No Weed Control plot while the lowest value was 24.36 % in the 10–15 cm Weed Wiper plot.

Table 4.20: Interaction effect of ploughing depth and weed control on dry bulk density, moisture content, total porosity and air content in the 0–15 cm layer on 5 August, 2009

Ploughing Depth x Weed Control	Dry Bulk Density ($Mg\ m^{-3}$)	Moisture Content (%)	Total Porosity (%)	Air Content (%)
0 cm x Cutlass	1.41	12.41	47.67	29.60
0 cm x Hoe	1.43	11.44	46.33	29.76
0 cm x Knapsack Sprayer	1.42	11.43	46.33	30.13
0 cm x No Weed Control	1.30	11.41	51.33	36.25
0 cm x Weed Wiper	1.46	11.16	45.33	28.80
10–15 cm x Cutlass	1.36	12.04	48.67	32.38
10–15 cm x Hoe	1.34	10.48	49.67	35.18
10–15 cm x Knapsack Sprayer	1.44	14.14	45.67	25.65
10–15 cm x No Weed Control	1.45	11.44	45.33	28.90
10–15 cm x Weed Wiper	1.48	13.43	61.67	24.36
15–20 cm x Cutlass	1.38	11.35	48.00	31.99
15–20 cm x Hoe	1.41	11.70	47.33	30.61
15–20 cm x Knapsack Sprayer	1.44	13.14	45.67	26.59
15–20 cm x No Weed Control	1.41	10.77	47.33	31.65
15–20 cm x Weed Wiper	1.39	11.57	47.67	31.65
20–25 cm x Cutlass	1.28	13.49	52.33	34.79
20–25 cm x Hoe	1.33	12.63	50.33	33.02
20–25 cm x Knapsack Sprayer	1.37	12.15	48.67	31.87
20–25 cm x No Weed Control	1.27	11.98	52.67	37.10
20–25 cm x Weed Wiper	1.31	12.52	50.67	34.11
Mean	1.38	12.03	48.93	31.22
LSD ($p < 0.05$)	NS	NS	NS	NS

4.5.9 Interaction effect of ploughing depth and weed control treatments on soil properties in the 0–15 cm layer on 5 October, 2009

Table 4.21 displays the mean values of the interaction effect of ploughing depth and weed control treatments on dry bulk density, moisture content, total porosity and air content in the

0–15 cm layer after harvest (5 October, 2009). Analysis of variance showed no significant difference in dry bulk density, moisture content, total porosity and air content in the 0–15 cm layer. The maximum dry bulk density (1.45 Mg m^{-3}) was located in the 0 cm x Hoe plot while the minimum dry bulk density (1.29 Mg m^{-3}) was found in the 10–15 cm x Cutlass and 10–15 cm x Hoe plots. In the case of moisture content, the maximum soil moisture content (15.77 %) was observed in the 15–20 cm x Knapsack Sprayer plot while the minimum moisture content (11.07 %) was found in the 0 cm x No Weed Control plot. The maximum total porosity (51.67 %) was located in the 0 cm x No Weed Control, 10–15 cm x Cutlass, and 10–15 cm x Hoe plots while the minimum total porosity (45.67 %) was observed in the 0 cm x Hoe plot. The maximum air content (37.28 %) was recorded in the 0 cm x No Weed Control plot while the minimum moisture content (24.94 %) was located in the 15–20 cm x Knapsack Sprayer plot.

Table 4.21: Interaction effect of ploughing depth and weed control on dry bulk density, moisture content, total porosity and air content in the 0–15 cm layer on 5 October, 2009

Ploughing Depth x Weed Control	Dry Bulk Density (Mg m^{-3})	Moisture Content (%)	Total Porosity (%)	Air Content (%)
0 cm x Cutlass	1.30	12.59	51.33	34.76
0 cm x Hoe	1.45	12.12	45.67	28.22
0 cm x Knapsack Sprayer	1.43	12.14	46.67	29.10
0 cm x No Weed Control	1.30	11.07	51.67	37.28
0 cm x Weed Wiper	1.36	11.78	49.33	33.06
10–15 cm x Cutlass	1.29	13.20	51.67	34.33
10–15 cm x Hoe	1.29	11.84	51.67	35.94
10–15 cm x Knapsack Sprayer	1.31	14.89	50.33	30.98
10–15 cm x No Weed Control	1.31	13.07	51.00	33.42
10–15 cm x Weed Wiper	1.31	13.88	50.67	32.52
15–20 cm x Cutlass	1.38	12.55	48.33	30.71
15–20 cm x Hoe	1.39	13.60	48.00	28.58
15–20 cm x Knapsack Sprayer	1.40	15.77	47.67	24.94
15–20 cm x No Weed Control	1.33	11.65	50.00	34.24
15–20 cm x Weed Wiper	1.36	12.73	49.33	31.59
20–25 cm x Cutlass	1.36	15.09	49.00	28.37
20–25 cm x Hoe	1.42	13.91	47.00	27.08
20–25 cm x Knapsack Sprayer	1.39	12.62	47.67	29.97
20–25 cm x No Weed Control	1.35	13.74	49.33	30.99
20–25 cm x Weed Wiper	1.35	12.44	49.33	28.89
Mean	1.35	13.03	49.28	31.25
LSD ($p < 0.05$)	NS	NS	NS	NS

4.5.10 Interaction effect of ploughing depth and weed control treatments on soil properties in the 15–30 cm layer on 20 May, 2009

Table 4.22 shows the mean values of the interaction effect of ploughing depth and weed control treatments on dry bulk density, moisture content, total porosity and air content in the

15–30 cm layer before ploughing on 20 May, 2009. There was no statistical significant difference in dry bulk density, moisture content, total porosity and air content in interaction effect between ploughing depth and weed control treatments. Dry bulk density values ranged between 1.42 Mg m^{-3} for 0 cm x Knapsack Sprayer and 1.22 Mg m^{-3} for 15–20 cm x Knapsack Sprayer and 20–25 cm x Weed Wiper. The 15–20 cm x Knapsack Sprayer treatment presented the maximum (12.08 %) while the 0 cm x Knapsack Sprayer treatment gave the minimum (8.68%) moisture contents. The highest total porosity (54.67 %) was recorded in the 20–25 cm x Weed Wiper plots while the lowest total porosity (47 %) was observed in the 0 cm x Knapsack Sprayer plots. The maximum (41.52 %) and minimum (33.37 %) air contents were found in the 20–25 cm x Weed Wiper and 10–15 cm x No Weed Control plots respectively.

Table 4.22: Interaction effect of ploughing depth and weed control on dry bulk density, moisture content, total porosity and air content in the 15–30 cm layer on 20 May, 2009

Ploughing Depth x Weed Control	Dry Bulk Density ($Mg\ m^{-3}$)	Moisture Content (%)	Total Porosity (%)	Air Content (%)
0 cm x Cutlass	1.35	10.04	49.67	36.08
0 cm x Hoe	1.40	8.99	47.67	35.06
0 cm x Knapsack Sprayer	1.42	8.68	47.00	36.58
0 cm x No Weed Control	1.31	9.59	50.67	38.03
0 cm x Weed Wiper	1.37	9.40	48.67	35.11
10–15 cm x Cutlass	1.36	7.92	48.67	37.86
10–15 cm x Hoe	1.36	10.04	49.60	35.92
10–15 cm x Knapsack Sprayer	1.32	10.72	51.00	36.20
10–15 cm x No Weed Control	1.40	9.82	47.33	33.37
10–15 cm x Weed Wiper	1.32	9.11	50.67	38.21
15–20 cm x Cutlass	1.31	9.58	51.00	38.24
15–20 cm x Hoe	1.27	10.51	52.67	38.75
15–20 cm x Knapsack Sprayer	1.22	12.08	54.00	39.36
15–20 cm x No Weed Control	1.32	8.82	50.33	38.80
15–20 cm x Weed Wiper	1.37	9.20	48.67	35.99
20–25 cm x Cutlass	1.32	11.33	50.67	35.21
20–25 cm x Hoe	1.23	10.47	54.00	41.00
20–25 cm x Knapsack Sprayer	1.32	8.80	50.67	39.08
20–25 cm x No Weed Control	1.32	10.60	50.67	36.60
20–25 cm x Weed Wiper	1.22	10.34	54.67	41.52
Mean	1.33	9.80	50.42	37.35
LSD ($p < 0.05$)	NS	NS	NS	NS

4.5.11 Interaction effect of ploughing depth and weed control treatments on soil properties in the 15–30 cm layer on 5 August, 2009

Table 4.23 portrays the mean values of the interaction effect of ploughing depth and weed control treatments on dry bulk density, moisture content, total porosity and air content in the

15–30 cm layer on 5 August, 2009. Analysis of variance showed no statistical significant difference in dry bulk density, moisture content, total porosity and air content in the 15–30 cm layer between the ploughing depth and weed control treatments. The 0 cm x Hoe treatment resulted in the maximum (1.48 Mg m^{-3}) dry bulk density. The 20–25 cm x Cutlass treatment presented the minimum (1.18 Mg m^{-3}) dry bulk density. The highest moisture content (14.06 %) was found in the 10–15 cm x Knapsack Sprayer plots while lowest moisture content (9.43 %) was located in the 15–20 cm x No Weed Control plots. The 20–25 cm x Cutlass treatment presented the highest total porosity (54 %) whereas the 0 cm x Hoe treatment resulted in the lowest (44.67 %) total porosity. Although, there was no significant difference, the 20–25 cm x Cutlass treatment gave the highest air content (39.18 %) while the 10–15 cm x Knapsack Sprayer treatment recorded the lowest air content (26.32 %).

Table 4.23: Interaction effect of ploughing depth and weed control on dry bulk density, moisture content, total porosity and air content in the 15–30 cm layer on 5 August, 2009

Ploughing Depth x Weed Control	Dry Bulk Density (Mg m^{-3})	Moisture Content (%)	Total Porosity (%)	Air Content (%)
0 cm x Cutlass	1.36	12.97	48.67	30.97
0 cm x Hoe	1.48	11.39	44.67	27.51
0 cm x Knapsack Sprayer	1.46	12.13	45.33	27.62
0 cm x No Weed Control	1.31	10.72	50.67	36.70
0 cm x Weed Wiper	1.44	11.55	46.00	29.21
10–15 cm x Cutlass	1.37	9.88	48.67	34.62
10–15 cm x Hoe	1.38	9.74	48.00	34.39
10–15 cm x Knapsack Sprayer	1-.43	14.06	46.33	26.32
10–15 cm x No Weed Control	1.38	9.83	48.67	34.66
10–15 cm Weed Wiper	1.46	12.72	45.00	26.39
15–20 cm x Cutlass	1.44	10.56	46.33	30.74
15–20 cm x Hoe	1.42	11.11	46.67	30.44
15–20 cm x Knapsack Sprayer	1.45	12.29	45.67	27.49
15–20 cm x No Weed Control	1.39	9.43	48.00	34.86
15–20 cm x Weed Wiper	1.40	10.74	47.67	32.09
20–25 cm x Cutlass	1.18	13.74	54.00	39.18
20–25 cm x Hoe	1.34	11.65	49.67	33.99
20–25 cm x Knapsack Sprayer	1.31	12.72	51.00	28.43
20–25 cm x No Weed Control	1.25	11.66	53.00	38.31
20–25 cm x Weed Wiper	1.27	11.97	52.67	37.15
Mean	1.38	11.54	48.34	32.05
LSD ($p < 0.05$)	NS	NS	NS	NS

4.5.12 Interaction effect of ploughing depth and weed control treatments on soil properties in the 15–30 cm layer on 5 October, 2009

The mean values of the dry bulk density, moisture content, total porosity and air content in the 15–30 cm layer as affected by ploughing depth and weed control treatments after harvest on 5 October, 2009 is shown in Table 4.24. Dry bulk density, moisture content, total porosity and air content were not significantly different between the different ploughing depth and weed control treatments. The highest dry bulk density (1.46 Mg m^{-3}) was recorded in the 20–25 cm x Hoe plots while the lowest dry bulk density (1.22 Mg m^{-3}) was found in the 0 cm x Cutlass plots. The 20–25 cm x Knapsack Sprayer treatment presented the maximum (16.06 %) moisture content whereas the 15–20 cm x No Weed Control treatment offered the minimum (11.05 %) moisture content. The highest total porosity (54.33 %) was recorded in the 0 cm x Cutlass plots while the lowest total porosity (45.33 %) was observed in the 20–25 cm x Hoe plots. The maximum air content of 38.54 % was obtained from the 0 cm x Cutlass plots while the minimum air content of 24.51 % was found in the 0 cm x Cutlass plots.

Table 4.24: Interaction effect of ploughing depth and weed control on dry bulk density, moisture content, total porosity and air content in the 15–30 cm layer on 5 October, 2009

Ploughing Depth x Weed Control	Dry Bulk Density ($Mg\ m^{-3}$)	Moisture Content (%)	Total Porosity (%)	Air Content (%)
0 cm x Cutlass	1.22	13.04	54.33	38.54
0 cm x Hoe	1.40	13.26	47.33	29.11
0 cm x Knapsack Sprayer	1.42	12.83	46.67	28.74
0 cm x No Weed Control	1.28	12.05	52.33	36.60
0 cm x Weed Wiper	1.33	13.02	50.33	32.68
10–15 cm x Cutlass	1.29	12.18	51.67	35.78
10–15 cm x Hoe	1.35	11.89	49.00	32.93
10–15 cm x Knapsack Sprayer	1.33	12.01	50.00	33.75
10–15 cm x No Weed Control	1.33	11.10	50.00	35.28
10–15 cm Weed Wiper	1.34	13.36	49.67	31.88
15–20 cm x Cutlass	1.43	12.92	46.33	27.60
15–20 cm x Hoe	1.39	14.24	48.00	27.72
15–20 cm x Knapsack Sprayer	1.42	14.89	46.33	25.11
15–20 cm x No Weed Control	1.36	11.05	49.00	33.90
15–20 cm x Weed Wiper	1.34	14.16	49.67	30.48
20–25 cm x Cutlass	1.39	14.01	48.00	27.94
20–25 cm x Hoe	1.46	14.27	45.33	24.51
20–25 cm x Knapsack Sprayer	1.36	16.06	49.00	27.01
20–25 cm x No Weed Control	1.44	14.63	46.33	24.83
20–25 cm x Weed Wiper	1.36	13.58	49.33	30.39
Mean	1.36	13.23	48.93	30.74
LSD ($p < 0.05$)	NS	NS	NS	NS

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The objectives of the study were to determine the effect of ploughing depth and weed control treatments on *obaatanpa* maize variety seedling emergence, plant height, stem girth, number of leaves, root length, and dry matter yield; to determine the effect of ploughing depth and weed control treatments on soil penetration resistance, dry bulk density, moisture content, total porosity and air content; and to determine the effect of ploughing depth on weed dry matter yield. Based on these objectives the following conclusions were drawn:

5.1.1 Effect of ploughing depth on seedling emergence

The highest *obaatanpa* maize seedling emergence of 86.13% was obtained from the 20–25 cm ploughing depth plots while the lowest seedling emergence of 84.53% was located in the 0 cm (No-Tillage) plots although there was no significant difference except for the first four days of seedling emergence.

5.1.2 Effect of ploughing depth and weed control treatments on plant height

Plant height was significantly affected by depth of ploughing. The results presented indicate that ploughing at 10–15 cm, 15–20 cm and 20–25 cm was superior to that at 0 cm (No Tillage) in increasing plant height. The tallest plant height (180.50 cm) was located in 15–20 cm ploughing depth plots ten weeks after planting. This was followed by the 20–25 cm (179.78 cm) and 10–15 cm (173.24 cm) ploughing depth treatments. The shortest plant height (104.98 cm) was found in the 0 cm ploughing depth (No Tillage) plots which was significantly smaller than that of the other ploughing depth treatments.

Unlike ploughing depth, weed control treatment did not have statistical significant difference in plant height between the different weed control treatments. However, the tallest plant height (170.53 cm) was found in the cutlass weed control plots while the shortest plant (143.04 cm) was in the knapsack sprayer plots.

There was no significant interaction effect of ploughing depth and weed control treatments on plant height. However, the tallest plant height (192.47 cm) was obtained by ploughing at 10–15 cm depth and controlling weeds with the hand hoe. The shortest plant height (87.51 cm) was found in the No Tillage x no weed control interaction plots.

5.1.3 Effect of ploughing depth and weed control treatments on stem girth

Ploughing depth treatments had significant effect on *obaatanpa* stem girth. Ten weeks after planting, the biggest values of stem girth (57.53 mm) was obtained from the 20–25 cm ploughing depth treatment while the smallest stem girth (36.49 mm) was found in the 0 cm ploughing depth (No Tillage) treatment. Significant effect in ploughing depth were in the order 20–25 cm (57.53 mm), 15–20 cm (57.11 mm), 10–15 cm (55.11 mm) > 0 cm (No Tillage) (36.49 mm).

There was no statistical significant difference in plant stem girth between the different weed control treatments. Ten weeks after planting, the biggest stem girth (52.42 mm) was obtained from the hoe weed control plots while the smallest stem girth (49.50 mm) was produced in the knapsack sprayer plots.

Analysis of variance did not show interaction effect of ploughing depth and weed control treatments on stem girth. The biggest stem girth (62.73 mm) was found in the 15–20 cm x no weed control plots while the smallest stem girth (32.83 mm) was located in the 0 cm (No Tillage) x no weed control plots.

5.1.4 Effect of ploughing depth and weed control treatments on number of leaves

Over the ten week study period, the highest number of leaves (17.71) was produced by the 10–15 cm ploughing depth treatment while the lowest number of leaves (14.87) was obtained from the 0 cm ploughing depth (No Tillage) treatment. The number of leaves in the 10–15 cm, 15–20 cm, and 20–25 cm ploughing depth plots were statistically similar. The number of leaves in the 10–15 cm, 15–20 cm, and 20–25 cm ploughing depths was significantly higher compared with the 0 cm ploughing depth.

There was statistical significant difference in the number of leaves between the weed control treatments. Weed control under the hoe presented the highest number of leaves (17.33). Weed control with the knapsack sprayer gave the lowest number of leaves (16.20).

The interaction effect of ploughing depth and weed control treatment on number of leaves was also not significant. The highest number of leaves of 18.17 was obtained from the 15–20 cm x cutlass or 15–20 cm x no weed control interaction effect. The smallest number of leaves of 13.56 was observed in the 0 cm x knapsack sprayer plots.

5.1.5 Effect of weed control treatment on root length and dry matter yield

Ploughing at the 20–25 cm depth produced the longest root length (46.34 cm) and highest dry matter yield (8155 kg ha^{-1}). The 0 cm ploughing depth (No Tillage) treatment presented the shortest root length (27.72 cm) and the lowest dry matter yield (2573 kg ha^{-1}). Weed control with the weed wiper resulted in the longest root length (41.85 cm) and the highest dry matter yield (6348 kg ha^{-1}). The shortest root length was observed in the knapsack sprayer plots (39.62 cm) with dry matter yield of 6315 kg ha^{-1}. The no weed control treatment produced root length of 40.26 cm and the smallest *obaatanpa* dry matter yield of 4348 kg ha^{-1}. These results emphasize the need for weed control in the production of maize.

There was no significant interaction effect of ploughing depth and weed control treatments on maize root length and dry matter yield. The longest root length (47.99 cm) was obtained from the interaction between the 20–25 cm ploughing depth and the Weed Wiper weed control treatments. The shortest root length (25.64 cm) and the smallest dry matter yield (1541 kg ha^{-1}) was observed in the 0cm x No Weed Control treatment combination. The highest dry matter yield (10020 kg ha^{-1}) was produced by the 20–25 cm x Knapsack Sprayer plots.

5.1.6 Dry matter yield of weeds

Weed dry matter decreased with increasing depth of ploughing suggesting that the deeper the depth of ploughing, the better the weed control. The lowest weed dry matter yield was 134.87 kg ha^{-1} for the deepest ploughing depth (20–25 cm) while the highest weed dry matter yield was 671.06 kg ha^{-1} for the 0 cm (No Tillage) treatment.

5.2 Soil properties

5.2.1 Effect of ploughing depth and weed control treatments on soil penetration resistance

Penetration resistance values between the different ploughing depths before ploughing (20 May 2009) and after planting (5 August 2009) were not significantly different. However, the 0 cm ploughing depth treatment (No Tillage) presented the highest penetration resistance significantly greater than that of the 10–15 cm, 15–20 cm, and 20–25 cm ploughing depths after harvest (5 October 2009). Weed control treatments did not affect soil penetration resistance before ploughing (20 May 2009), after planting (5 August 2009) and after harvest (5 October 2009). Similarly, there was no significant interaction effect of ploughing depth and weed control treatments on soil penetration resistance during the study period.

5.2.2 Effect of ploughing depth and weed control treatments on dry bulk density

Over the period of the study, soil dry bulk density was not significantly affected by ploughing depth treatment except for 5 August 2009 (67 DAP) when there was significant difference in both the 0–15 cm and 15–30 cm depth layers. Dry bulk density in the 20–25 cm depth treatment was significantly lower compared with the other ploughing depth treatments. Weed control treatments did not significantly affect dry bulk density in the 0–15 cm and 15–30 cm depth layers before ploughing (20 May 2009), after planting (5 August 2009) and after harvest (5 October 2009). Likewise, there was no significant interaction ploughing depth and weed control effect on soil dry bulk density in both the 0–15 cm and 15–30 cm depth layers over the course of the experiment.

5.2.3 Effect of ploughing depth and weed control treatment on soil moisture content

The results from the study showed that the highest moisture content was obtained from the 20–25 cm ploughing depth treatment over the course of the study although there was no ploughing depth significant effect on soil moisture content before ploughing and after planting except for that after harvest. Ploughing at the 20–25 cm depth significantly increased gravimetric soil moisture content in comparison with the 0 cm depth (No Tillage) treatment in the 0–15 cm layer. Similarly, the 20–25 cm ploughing depth treatment produced significant moisture content effect compared with the other ploughing depth treatments in the 15–30 cm layer.

Throughout the study period, the highest moisture content was recorded in the knapsack sprayer plots. Similarly, the lowest soil moisture content was observed in the no weed control plots (except for 20 May 2009 in the 0–15 cm layer). Overall, weed control treatment did not have significant effect on soil moisture content with the exception of 5 August 2009 when soil moisture content in the 15–30 cm layer was significantly higher in the knapsack sprayer plots compared with that of the other weed control treatment plots.

The study results also indicated that there was no significant interaction effect of ploughing depth and weed control treatment effect on soil moisture content.

5.2.4 Effect of ploughing depth and weed control treatments on total porosity

The highest total soil porosity before ploughing and after planting was located in the 20–25 cm ploughing depth plots. Ploughing depth did not significantly influence total porosity for all sampling dates except for 5 August 2009 (67 DAP) in the 15–30 cm layer. On this date, the 20–25 cm ploughing depth treatment produced total soil porosity significantly greater than that of the other ploughing depth treatments. Total porosity was not significantly affected by the different control treatments. Similarly, there was no statistical significant interaction effect on total porosity between the ploughing depth and weed control treatments

5.2.5 Effect of ploughing depth and weed control treatments on air content

The results of the study showed that soil air content was statistically similar between the different ploughing depth treatments throughout the study period. The highest soil air content was located in the 20–25 cm ploughing depth plots before ploughing and after planting. However, after harvest, the 20–25 cm ploughing depth plots presented the lowest air content in both the 0–15 cm layer and 15–30 cm layer.

Soil air content was not significantly influenced by weed control treatments. Similarly, there was no significant interaction effect of ploughing depth and weed control treatments on soil air content.

5.3 RECOMMENDATIONS

There is the need to determine the long–term effects of ploughing depth and weed control treatments on maize growth and yield, and soil chemical and physical properties including sand, silt, clay, pH, organic carbon, organic matter, total N, exchangeable cations including Ca, Mg, K, and NH_4^+N, and available P; penetration resistance, dry bulk density, moisture content, air content and porosity.

The experiment should be continued to determine the optimum ploughing depth for other maize varieties such as *okomasa*, *mamaba*, *dadaba*, as well as other crops including cowpea, soyabean, groundnut, rice, sorghum, millet, tomato, pepper and garden egg.

Economic analysis should also be undertaken to determine costs and benefits of the effect of ploughing depth and weed control treatments on maize performance and soil properties.

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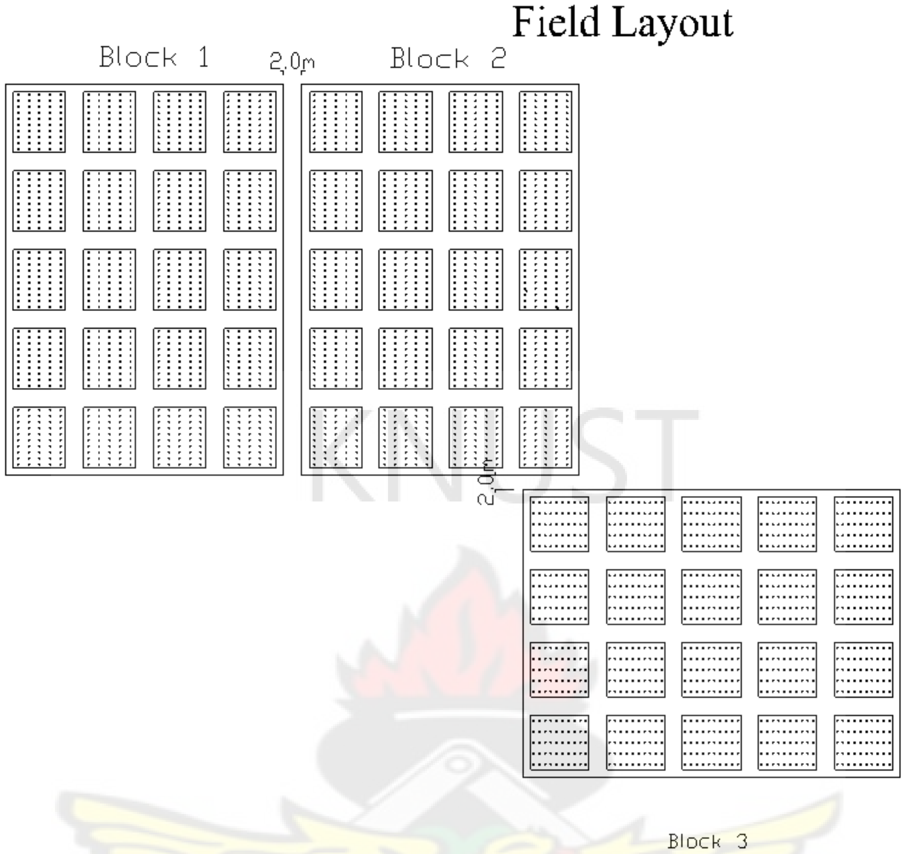
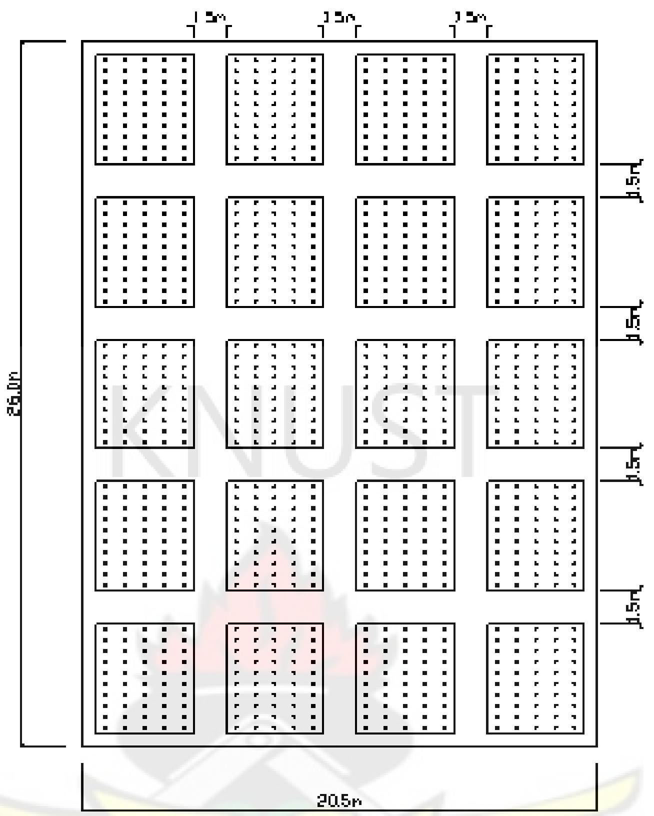
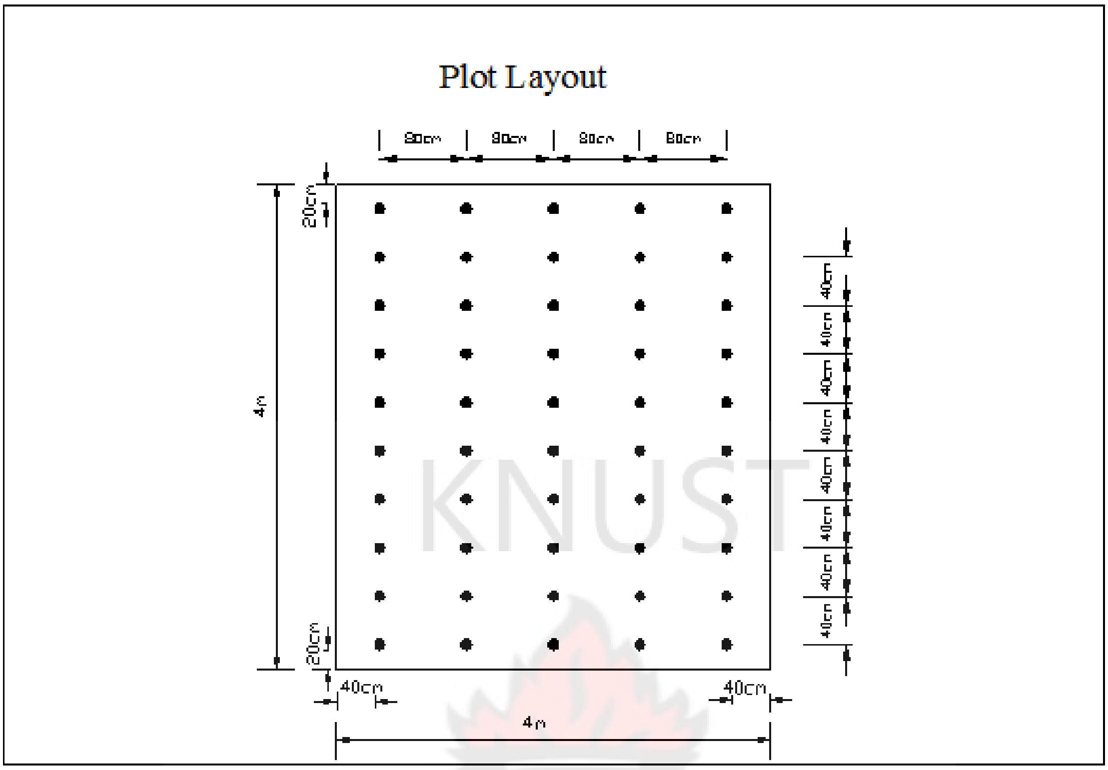
APPENDICES

APPENDIX 1: FIELD PLAN



Block Layout





Plot Layout
80cm
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APPENDIX 2: MINITAB STATISTICAL SOFTWARE OUTPUT
SEEDLING EMERGENCE

3rd June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

```
Factor            Type   Levels  Values
Block             fixed       3  1, 2, 3
Ploughing Depth   fixed       4  0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control      fixed       5  Cutlass, Hoe, Knapsack Sprayer, No Weed
                                 Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests
Source                         DF   Seq SS   Adj SS  Adj MS     F      P
Block                           2   673.30   673.30  336.65  7.81  0.001
Ploughing Depth                 3  1233.13  1233.13  411.04  9.53  0.000
Weed Control                    4    61.23    61.23   15.31  0.35  0.839
Ploughing Depth*Weed Control   12   331.03   331.03   27.59  0.64  0.795
Error                          38  1638.70  1638.70   43.12
Total                          59  3937.40

S = 6.56686   R-Sq = 58.38%   R-Sq(adj) = 35.38%

Unusual Observations for Emergence (%)
     Emergence
Obs        (%)      Fit  SE Fit  Residual  St Resid
  6    24.0000  12.7833  3.9764   11.2167      2.15 R
 29    40.0000  20.3500  3.9764   19.6500      3.76 R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)
Ploughing De                      Mean  SE Mean
0 cm                            0.1333    1.696
10 - 15 cm                     11.0000    1.696
15 - 20 cm                     11.0667    1.696
20 - 25 cm                      9.4000    1.696
Weed Control
Cutlass                         7.3333    1.896
Hoe                             6.5833    1.896
Knapsack Sprayer                7.4167    1.896
No Weed Control                 9.0000    1.896
Weed Wiper                      9.1667    1.896
Ploughing De*Weed Control
0 cm          Cutlass           0.6667    3.791
0 cm          Hoe               0.0000    3.791
0 cm          Knapsack Sprayer -0.0000    3.791
0 cm          No Weed Control  -0.0000    3.791
0 cm          Weed Wiper       -0.0000    3.791
10 - 15 cm    Cutlass           9.6667    3.791
10 - 15 cm    Hoe               7.3333    3.791
10 - 15 cm    Knapsack Sprayer  8.6667    3.791
10 - 15 cm    No Weed Control  13.3333    3.791
10 - 15 cm    Weed Wiper       16.0000    3.791
15 - 20 cm    Cutlass           7.3333    3.791
15 - 20 cm    Hoe              11.6667    3.791
15 - 20 cm    Knapsack Sprayer 16.0000    3.791
15 - 20 cm    No Weed Control  10.3333    3.791
15 - 20 cm    Weed Wiper       10.0000    3.791
20 - 25 cm    Cutlass          11.6667    3.791
20 - 25 cm    Hoe               7.3333    3.791
20 - 25 cm    Knapsack Sprayer  5.0000    3.791
20 - 25 cm    No Weed Control  12.3333    3.791
20 - 25 cm    Weed Wiper       10.6667    3.791
```

4th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

```
Factor            Type   Levels  Values
```

```
Block             fixed       3  1, 2, 3
Ploughing Depth   fixed       4  0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control      fixed       5  Cutlass, Hoe, Knapsack Sprayer, No Weed
                                 Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests
Source                         DF    Seq SS    Adj SS  Adj MS      F      P
Block                           2    3635.1    3635.1  1817.5  17.86  0.000
Ploughing Depth                 3   18738.6   18738.6  6246.2  61.37  0.000
Weed Control                    4     424.8     424.8   106.2   1.04  0.398
Ploughing Depth*Weed Control   12    1418.8    1418.8   118.2   1.16  0.344
Error                          38    3867.6    3867.6   101.8
Total                          59   28084.9

S = 10.0885   R-Sq = 86.23%   R-Sq(adj) = 78.62%

Unusual Observations for Emergence (%)
     Emergence
Obs        (%)      Fit  SE Fit  Residual  St Resid
 11    34.0000  57.5000  6.1089  -23.5000     -2.93 R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)
Ploughing De                     Mean  SE Mean
0 cm                           12.933    2.605
10 - 15 cm                     55.667    2.605
15 - 20 cm                     51.800    2.605
20 - 25 cm                     53.400    2.605
Weed Control
Cutlass                        42.417    2.912
Hoe                            42.333    2.912
Knapsack Sprayer               41.750    2.912
No Weed Control                48.750    2.912
Weed Wiper                     42.000    2.912
Ploughing De*Weed Control
0 cm          Cutlass          12.667    5.825
0 cm          Hoe              14.000    5.825
0 cm          Knapsack Sprayer  7.333    5.825
0 cm          No Weed Control  21.333    5.825
0 cm          Weed Wiper        9.333    5.825
10 - 15 cm    Cutlass          53.000    5.825
10 - 15 cm    Hoe              45.333    5.825
10 - 15 cm    Knapsack Sprayer 50.667    5.825
10 - 15 cm    No Weed Control  66.333    5.825
10 - 15 cm    Weed Wiper       63.000    5.825
15 - 20 cm    Cutlass          46.333    5.825
15 - 20 cm    Hoe              54.667    5.825
15 - 20 cm    Knapsack Sprayer 52.000    5.825
15 - 20 cm    No Weed Control  53.000    5.825
15 - 20 cm    Weed Wiper       53.000    5.825
20 - 25 cm    Cutlass          57.667    5.825
20 - 25 cm    Hoe              55.333    5.825
20 - 25 cm    Knapsack Sprayer 57.000    5.825
20 - 25 cm    No Weed Control  54.333    5.825
20 - 25 cm    Weed Wiper       42.667    5.825
```

5th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

```
Factor            Type   Levels  Values
Block             fixed       3  1, 2, 3
Ploughing Depth   fixed       4  0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control      fixed       5  Cutlass, Hoe, Knapsack Sprayer, No Weed
                                 Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests
Source                         DF    Seq SS   Adj SS   Adj MS      F      P
```

Block	2	531.7	531.7	265.8	2.25	0.119
Ploughing Depth	3	9677.0	9677.0	3225.7	27.29	0.000
Weed Control	4	125.4	125.4	31.4	0.27	0.898
Ploughing Depth*Weed Control	12	648.6	648.6	54.1	0.46	0.927
Error	38	4491.0	4491.0	118.2		
Total	59	15473.6				

S = 10.8712   R-Sq = 70.98%   R-Sq(adj) = 54.94%

Unusual Observations for Emergence (%)

Obs	Emergence (%)	Fit	SE Fit	Residual	St Resid	
11	45.0000	69.1833	6.5828	-24.1833	-2.80	R
22	20.0000	41.6833	6.5828	-21.6833	-2.51	R
50	43.0000	64.4667	6.5828	-21.4667	-2.48	R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)

Ploughing De		Mean	SE Mean
0 cm		41.40	2.807
10 - 15 cm		71.87	2.807
15 - 20 cm		69.53	2.807
20 - 25 cm		70.60	2.807
Weed Control			
Cutlass		63.08	3.138
Hoe		62.50	3.138
Knapsack Sprayer		61.33	3.138
No Weed Control		64.33	3.138
Weed Wiper		65.50	3.138
Ploughing De*Weed Control			
0 cm	Cutlass	37.67	6.276
0 cm	Hoe	39.33	6.276
0 cm	Knapsack Sprayer	39.00	6.276
0 cm	No Weed Control	48.67	6.276
0 cm	Weed Wiper	42.33	6.276
10 - 15 cm	Cutlass	72.33	6.276
10 - 15 cm	Hoe	65.67	6.276
10 - 15 cm	Knapsack Sprayer	68.67	6.276
10 - 15 cm	No Weed Control	75.67	6.276
10 - 15 cm	Weed Wiper	77.00	6.276
15 - 20 cm	Cutlass	69.67	6.276
15 - 20 cm	Hoe	74.33	6.276
15 - 20 cm	Knapsack Sprayer	64.67	6.276
15 - 20 cm	No Weed Control	67.33	6.276
15 - 20 cm	Weed Wiper	71.67	6.276
20 - 25 cm	Cutlass	72.67	6.276
20 - 25 cm	Hoe	70.67	6.276
20 - 25 cm	Knapsack Sprayer	73.00	6.276
20 - 25 cm	No Weed Control	65.67	6.276
20 - 25 cm	Weed Wiper	71.00	6.276

6th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	554.63	554.63	277.32	3.06	0.058
Ploughing Depth	3	2920.07	2920.07	973.36	10.75	0.000
Weed Control	4	147.23	147.23	36.81	0.41	0.803
Ploughing Depth*Weed Control	12	612.10	612.10	51.01	0.56	0.857
Error	38	3440.70	3440.70	90.54		

Total	59	7674.73

S = 9.51550   R-Sq = 55.17%   R-Sq(adj) = 30.39%

Unusual Observations for Emergence (%)

Obs	Emergence (%)	Fit	SE Fit	Residual	St Resid	
11	62.0000	77.8000	5.7619	-15.8000	-2.09	R
25	36.0000	54.6500	5.7619	-18.6500	-2.46	R
50	52.0000	69.5500	5.7619	-17.5500	-2.32	R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)

Ploughing De		Mean	SE Mean
0 cm		59.60	2.457
10 - 15 cm		77.13	2.457
15 - 20 cm		74.80	2.457
20 - 25 cm		74.73	2.457
Weed Control			
Cutlass		71.33	2.747
Hoe		71.75	2.747
Knapsack Sprayer		69.00	2.747
No Weed Control		71.83	2.747
Weed Wiper		73.92	2.747
Ploughing De*Weed Control			
0 cm	Cutlass	54.67	5.494
0 cm	Hoe	64.00	5.494
0 cm	Knapsack Sprayer	53.67	5.494
0 cm	No Weed Control	63.33	5.494
0 cm	Weed Wiper	62.33	5.494
10 - 15 cm	Cutlass	78.33	5.494
10 - 15 cm	Hoe	72.67	5.494
10 - 15 cm	Knapsack Sprayer	73.67	5.494
10 - 15 cm	No Weed Control	80.00	5.494
10 - 15 cm	Weed Wiper	81.00	5.494
15 - 20 cm	Cutlass	74.33	5.494
15 - 20 cm	Hoe	76.67	5.494
15 - 20 cm	Knapsack Sprayer	70.00	5.494
15 - 20 cm	No Weed Control	74.67	5.494
15 - 20 cm	Weed Wiper	78.33	5.494
20 - 25 cm	Cutlass	78.00	5.494
20 - 25 cm	Hoe	73.67	5.494
20 - 25 cm	Knapsack Sprayer	78.67	5.494
20 - 25 cm	No Weed Control	69.33	5.494
20 - 25 cm	Weed Wiper	74.00	5.494

7th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	422.10	422.10	211.05	3.49	0.041
Ploughing Depth	3	470.05	470.05	156.68	2.59	0.067
Weed Control	4	177.43	177.43	44.36	0.73	0.575
Ploughing Depth*Weed Control	12	293.37	293.37	24.45	0.40	0.953
Error	38	2297.90	2297.90	60.47		
Total	59	3660.85				

S = 7.77631   R-Sq = 37.23%   R-Sq(adj) = 2.54%

Unusual Observations for Emergence (%)

Obs	Emergence (%)	Fit	SE Fit	Residual	St Resid
50	59.0000	74.2500	4.7088	-15.2500	-2.46 R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)

Ploughing De		Mean	SE Mean
0 cm		73.73	2.008
10 - 15 cm		81.53	2.008
15 - 20 cm		78.13	2.008
20 - 25 cm		78.80	2.008
Weed Control			
Cutlass		79.42	2.245
Hoe		78.50	2.245
Knapsack Sprayer		75.58	2.245
No Weed Control		76.58	2.245
Weed Wiper		80.17	2.245
Ploughing De*Weed Control			
0 cm	Cutlass	72.33	4.490
0 cm	Hoe	76.33	4.490
0 cm	Knapsack Sprayer	70.00	4.490
0 cm	No Weed Control	71.00	4.490
0 cm	Weed Wiper	79.00	4.490
10 - 15 cm	Cutlass	84.33	4.490
10 - 15 cm	Hoe	78.67	4.490
10 - 15 cm	Knapsack Sprayer	78.00	4.490
10 - 15 cm	No Weed Control	82.33	4.490
10 - 15 cm	Weed Wiper	84.33	4.490
15 - 20 cm	Cutlass	78.00	4.490
15 - 20 cm	Hoe	79.67	4.490
15 - 20 cm	Knapsack Sprayer	74.33	4.490
15 - 20 cm	No Weed Control	78.67	4.490
15 - 20 cm	Weed Wiper	80.00	4.490
20 - 25 cm	Cutlass	83.00	4.490
20 - 25 cm	Hoe	79.33	4.490
20 - 25 cm	Knapsack Sprayer	80.00	4.490
20 - 25 cm	No Weed Control	74.33	4.490
20 - 25 cm	Weed Wiper	77.33	4.490

8th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	195.10	195.10	97.55	2.32	0.112
Ploughing Depth	3	49.33	49.33	16.44	0.39	0.760
Weed Control	4	104.73	104.73	26.18	0.62	0.649
Ploughing Depth*Weed Control	12	264.33	264.33	22.03	0.52	0.886
Error	38	1598.90	1598.90	42.08		
Total	59	2212.40				

S = 6.48663   R-Sq = 27.73%   R-Sq(adj) = 0.00%

Unusual Observations for Emergence (%)

Obs	Emergence (%)	Fit	SE Fit	Residual	St Resid
50	67.0000	78.1167	3.9278	-11.1167	-2.15 R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)

Ploughing De		Mean	SE Mean
0 cm		80.13	1.675
10 - 15 cm		82.67	1.675
15 - 20 cm		81.60	1.675
20 - 25 cm		81.20	1.675
Weed Control			
Cutlass		82.42	1.873
Hoe		81.33	1.873
Knapsack Sprayer		80.42	1.873
No Weed Control		79.58	1.873
Weed Wiper		83.25	1.873
Ploughing De*Weed Control			
0 cm	Cutlass	79.67	3.745
0 cm	Hoe	81.00	3.745
0 cm	Knapsack Sprayer	75.67	3.745
0 cm	No Weed Control	78.33	3.745
0 cm	Weed Wiper	86.00	3.745
10 - 15 cm	Cutlass	85.00	3.745
10 - 15 cm	Hoe	80.00	3.745
10 - 15 cm	Knapsack Sprayer	80.67	3.745
10 - 15 cm	No Weed Control	82.33	3.745
10 - 15 cm	Weed Wiper	85.33	3.745
15 - 20 cm	Cutlass	80.00	3.745
15 - 20 cm	Hoe	82.33	3.745
15 - 20 cm	Knapsack Sprayer	83.67	3.745
15 - 20 cm	No Weed Control	79.67	3.745
15 - 20 cm	Weed Wiper	82.33	3.745
20 - 25 cm	Cutlass	85.00	3.745
20 - 25 cm	Hoe	82.00	3.745
20 - 25 cm	Knapsack Sprayer	81.67	3.745
20 - 25 cm	No Weed Control	78.00	3.745
20 - 25 cm	Weed Wiper	79.33	3.745

9th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	192.93	192.93	96.47	3.91	0.029
Ploughing Depth	3	12.60	12.60	4.20	0.17	0.916
Weed Control	4	68.10	68.10	17.03	0.69	0.604
Ploughing Depth*Weed Control	12	235.90	235.90	19.66	0.80	0.652
Error	38	938.40	938.40	24.69		
Total	59	1447.93				

S = 4.96938   R-Sq = 35.19%   R-Sq(adj) = 0.00%

Unusual Observations for Emergence (%)

Obs	Emergence (%)	Fit	SE Fit	Residual	St Resid
25	70.0000	82.8333	3.0091	-12.8333	-3.25 R
50	69.0000	80.4667	3.0091	-11.4667	-2.90 R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)

Ploughing De	Mean	SE Mean
0 cm	84.27	1.283
10 - 15 cm	85.47	1.283
15 - 20 cm	85.13	1.283

20 - 25 cm		85.27	1.283
Weed Control			
Cutlass		85.58	1.435
Hoe		86.50	1.435
Knapsack Sprayer		84.50	1.435
No Weed Control		83.33	1.435
Weed Wiper		85.25	1.435
Ploughing De*Weed Control			
0 cm	Cutlass	82.67	2.869
0 cm	Hoe	85.00	2.869
0 cm	Knapsack Sprayer	81.67	2.869
0 cm	No Weed Control	83.33	2.869
0 cm	Weed Wiper	88.67	2.869
10 - 15 cm	Cutlass	88.67	2.869
10 - 15 cm	Hoe	84.33	2.869
10 - 15 cm	Knapsack Sprayer	83.00	2.869
10 - 15 cm	No Weed Control	85.67	2.869
10 - 15 cm	Weed Wiper	85.67	2.869
15 - 20 cm	Cutlass	84.33	2.869
15 - 20 cm	Hoe	88.33	2.869
15 - 20 cm	Knapsack Sprayer	86.67	2.869
15 - 20 cm	No Weed Control	83.00	2.869
15 - 20 cm	Weed Wiper	83.33	2.869
20 - 25 cm	Cutlass	86.67	2.869
20 - 25 cm	Hoe	88.33	2.869
20 - 25 cm	Knapsack Sprayer	86.67	2.869
20 - 25 cm	No Weed Control	81.33	2.869
20 - 25 cm	Weed Wiper	83.33	2.869

10th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	206.63	206.63	103.32	4.10	0.024
Ploughing Depth	3	20.45	20.45	6.82	0.27	0.846
Weed Control	4	71.33	71.33	17.83	0.71	0.591
Ploughing Depth*Weed Control	12	225.47	225.47	18.79	0.75	0.698
Error	38	956.70	956.70	25.18		
Total	59	1480.58				

S = 5.01760   R-Sq = 35.38%   R-Sq(adj) = 0.00%

Unusual Observations for Emergence (%)

Obs	Emergence (%)	Fit	SE Fit	Residual	St Resid
25	70.0000	83.1500	3.0383	-13.1500	-3.29 R
50	69.0000	80.3833	3.0383	-11.3833	-2.85 R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)

Ploughing De	Mean	SE Mean
0 cm	84.53	1.296
10 - 15 cm	85.67	1.296
15 - 20 cm	85.33	1.296
20 - 25 cm	86.13	1.296
Weed Control		
Cutlass	86.33	1.448
Hoe	86.92	1.448
Knapsack Sprayer	84.50	1.448
No Weed Control	84.00	1.448

Weed Wiper		85.33	1.448
Ploughing De*Weed Control			
0 cm	Cutlass	83.00	2.897
0 cm	Hoe	86.00	2.897
0 cm	Knapsack Sprayer	81.67	2.897
0 cm	No Weed Control	83.33	2.897
0 cm	Weed Wiper	88.67	2.897
10 - 15 cm	Cutlass	88.67	2.897
10 - 15 cm	Hoe	85.00	2.897
10 - 15 cm	Knapsack Sprayer	83.00	2.897
10 - 15 cm	No Weed Control	86.00	2.897
10 - 15 cm	Weed Wiper	85.67	2.897
15 - 20 cm	Cutlass	84.33	2.897
15 - 20 cm	Hoe	88.33	2.897
15 - 20 cm	Knapsack Sprayer	86.67	2.897
15 - 20 cm	No Weed Control	84.00	2.897
15 - 20 cm	Weed Wiper	83.33	2.897
20 - 25 cm	Cutlass	89.33	2.897
20 - 25 cm	Hoe	88.33	2.897
20 - 25 cm	Knapsack Sprayer	86.67	2.897
20 - 25 cm	No Weed Control	82.67	2.897
20 - 25 cm	Weed Wiper	83.67	2.897

11th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	209.63	209.63	104.82	4.15	0.023
Ploughing Depth	3	20.33	20.33	6.78	0.27	0.848
Weed Control	4	73.23	73.23	18.31	0.72	0.580
Ploughing Depth*Weed Control	12	221.83	221.83	18.49	0.73	0.712
Error	38	959.70	959.70	25.26		
Total	59	1484.73				

S = 5.02546   R-Sq = 35.36%   R-Sq(adj) = 0.00%

Unusual Observations for Emergence (%)

Obs	Emergence (%)	Fit	SE Fit	Residual	St Resid
25	70.0000	83.1833	3.0431	-13.1833	-3.30 R
50	69.0000	80.3667	3.0431	-11.3667	-2.84 R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)

Ploughing De		Mean	SE Mean
0 cm		84.53	1.298
10 - 15 cm		85.67	1.298
15 - 20 cm		85.40	1.298
20 - 25 cm		86.13	1.298
Weed Control			
Cutlass		86.42	1.451
Hoe		86.92	1.451
Knapsack Sprayer		84.50	1.451
No Weed Control		84.00	1.451
Weed Wiper		85.33	1.451
Ploughing De*Weed Control			
0 cm	Cutlass	83.00	2.901
0 cm	Hoe	86.00	2.901
0 cm	Knapsack Sprayer	81.67	2.901

0 cm	No Weed Control	83.33	2.901
0 cm	Weed Wiper	88.67	2.901
10 - 15 cm	Cutlass	88.67	2.901
10 - 15 cm	Hoe	85.00	2.901
10 - 15 cm	Knapsack Sprayer	83.00	2.901
10 - 15 cm	No Weed Control	86.00	2.901
10 - 15 cm	Weed Wiper	85.67	2.901
15 - 20 cm	Cutlass	84.67	2.901
15 - 20 cm	Hoe	88.33	2.901
15 - 20 cm	Knapsack Sprayer	86.67	2.901
15 - 20 cm	No Weed Control	84.00	2.901
15 - 20 cm	Weed Wiper	83.33	2.901
20 - 25 cm	Cutlass	89.33	2.901
20 - 25 cm	Hoe	88.33	2.901
20 - 25 cm	Knapsack Sprayer	86.67	2.901
20 - 25 cm	No Weed Control	82.67	2.901
20 - 25 cm	Weed Wiper	83.67	2.901

12th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	209.63	209.63	104.82	4.15	0.023
Ploughing Depth	3	20.33	20.33	6.78	0.27	0.848
Weed Control	4	73.23	73.23	18.31	0.72	0.580
Ploughing Depth*Weed Control	12	221.83	221.83	18.49	0.73	0.712
Error	38	959.70	959.70	25.26		
Total	59	1484.73				

S = 5.02546   R-Sq = 35.36%   R-Sq(adj) = 0.00%

Unusual Observations for Emergence (%)

Obs	Emergence (%)	Fit	SE Fit	Residual	St Resid
25	70.0000	83.1833	3.0431	-13.1833	-3.30 R
50	69.0000	80.3667	3.0431	-11.3667	-2.84 R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)

Ploughing De		Mean	SE Mean
0 cm		84.53	1.298
10 - 15 cm		85.67	1.298
15 - 20 cm		85.40	1.298
20 - 25 cm		86.13	1.298
Weed Control			
Cutlass		86.42	1.451
Hoe		86.92	1.451
Knapsack Sprayer		84.50	1.451
No Weed Control		84.00	1.451
Weed Wiper		85.33	1.451
Ploughing De*Weed Control			
0 cm	Cutlass	83.00	2.901
0 cm	Hoe	86.00	2.901
0 cm	Knapsack Sprayer	81.67	2.901
0 cm	No Weed Control	83.33	2.901
0 cm	Weed Wiper	88.67	2.901
10 - 15 cm	Cutlass	88.67	2.901
10 - 15 cm	Hoe	85.00	2.901
10 - 15 cm	Knapsack Sprayer	83.00	2.901
10 - 15 cm	No Weed Control	86.00	2.901

10 - 15 cm	Weed Wiper	85.67	2.901
15 - 20 cm	Cutlass	84.67	2.901
15 - 20 cm	Hoe	88.33	2.901
15 - 20 cm	Knapsack Sprayer	86.67	2.901
15 - 20 cm	No Weed Control	84.00	2.901
15 - 20 cm	Weed Wiper	83.33	2.901
20 - 25 cm	Cutlass	89.33	2.901
20 - 25 cm	Hoe	88.33	2.901
20 - 25 cm	Knapsack Sprayer	86.67	2.901
20 - 25 cm	No Weed Control	82.67	2.901
20 - 25 cm	Weed Wiper	83.67	2.901

13th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	209.63	209.63	104.82	4.15	0.023
Ploughing Depth	3	20.33	20.33	6.78	0.27	0.848
Weed Control	4	73.23	73.23	18.31	0.72	0.580
Ploughing Depth*Weed Control	12	221.83	221.83	18.49	0.73	0.712
Error	38	959.70	959.70	25.26		
Total	59	1484.73				

S = 5.02546   R-Sq = 35.36%   R-Sq(adj) = 0.00%

Unusual Observations for Emergence (%)

Obs	Emergence (%)	Fit	SE Fit	Residual	St Resid
25	70.0000	83.1833	3.0431	-13.1833	-3.30 R
50	69.0000	80.3667	3.0431	-11.3667	-2.84 R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)

Ploughing De		Mean	SE Mean
0 cm		84.53	1.298
10 - 15 cm		85.67	1.298
15 - 20 cm		85.40	1.298
20 - 25 cm		86.13	1.298
Weed Control			
Cutlass		86.42	1.451
Hoe		86.92	1.451
Knapsack Sprayer		84.50	1.451
No Weed Control		84.00	1.451
Weed Wiper		85.33	1.451
Ploughing De*Weed Control			
0 cm	Cutlass	83.00	2.901
0 cm	Hoe	86.00	2.901
0 cm	Knapsack Sprayer	81.67	2.901
0 cm	No Weed Control	83.33	2.901
0 cm	Weed Wiper	88.67	2.901
10 - 15 cm	Cutlass	88.67	2.901
10 - 15 cm	Hoe	85.00	2.901
10 - 15 cm	Knapsack Sprayer	83.00	2.901
10 - 15 cm	No Weed Control	86.00	2.901
10 - 15 cm	Weed Wiper	85.67	2.901
15 - 20 cm	Cutlass	84.67	2.901
15 - 20 cm	Hoe	88.33	2.901
15 - 20 cm	Knapsack Sprayer	86.67	2.901

15 - 20 cm	No Weed Control	84.00	2.901
15 - 20 cm	Weed Wiper	83.33	2.901
20 - 25 cm	Cutlass	89.33	2.901
20 - 25 cm	Hoe	88.33	2.901
20 - 25 cm	Knapsack Sprayer	86.67	2.901
20 - 25 cm	No Weed Control	82.67	2.901
20 - 25 cm	Weed Wiper	83.67	2.901

14th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	209.63	209.63	104.82	4.15	0.023
Ploughing Depth	3	20.33	20.33	6.78	0.27	0.848
Weed Control	4	73.23	73.23	18.31	0.72	0.580
Ploughing Depth*Weed Control	12	221.83	221.83	18.49	0.73	0.712
Error	38	959.70	959.70	25.26		
Total	59	1484.73				

S = 5.02546   R-Sq = 35.36%   R-Sq(adj) = 0.00%

Unusual Observations for Emergence (%)

Obs	Emergence (%)	Fit	SE Fit	Residual	St Resid
25	70.0000	83.1833	3.0431	-13.1833	-3.30 R
50	69.0000	80.3667	3.0431	-11.3667	-2.84 R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)

Ploughing De		Mean	SE Mean
0 cm		84.53	1.298
10 - 15 cm		85.67	1.298
15 - 20 cm		85.40	1.298
20 - 25 cm		86.13	1.298
Weed Control			
Cutlass		86.42	1.451
Hoe		86.92	1.451
Knapsack Sprayer		84.50	1.451
No Weed Control		84.00	1.451
Weed Wiper		85.33	1.451
Ploughing De*Weed Control			
0 cm	Cutlass	83.00	2.901
0 cm	Hoe	86.00	2.901
0 cm	Knapsack Sprayer	81.67	2.901
0 cm	No Weed Control	83.33	2.901
0 cm	Weed Wiper	88.67	2.901
10 - 15 cm	Cutlass	88.67	2.901
10 - 15 cm	Hoe	85.00	2.901
10 - 15 cm	Knapsack Sprayer	83.00	2.901
10 - 15 cm	No Weed Control	86.00	2.901
10 - 15 cm	Weed Wiper	85.67	2.901
15 - 20 cm	Cutlass	84.67	2.901
15 - 20 cm	Hoe	88.33	2.901
15 - 20 cm	Knapsack Sprayer	86.67	2.901
15 - 20 cm	No Weed Control	84.00	2.901
15 - 20 cm	Weed Wiper	83.33	2.901
20 - 25 cm	Cutlass	89.33	2.901
20 - 25 cm	Hoe	88.33	2.901
20 - 25 cm	Knapsack Sprayer	86.67	2.901
20 - 25 cm	No Weed Control	82.67	2.901

20 - 25 cm	Weed Wiper	83.67	2.901

15th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	209.63	209.63	104.82	4.15	0.023
Ploughing Depth	3	20.33	20.33	6.78	0.27	0.848
Weed Control	4	73.23	73.23	18.31	0.72	0.580
Ploughing Depth*Weed Control	12	221.83	221.83	18.49	0.73	0.712
Error	38	959.70	959.70	25.26		
Total	59	1484.73				

S = 5.02546   R-Sq = 35.36%   R-Sq(adj) = 0.00%

Unusual Observations for Emergence (%)

Obs	Emergence (%)	Fit	SE Fit	Residual	St Resid	
25	70.0000	83.1833	3.0431	-13.1833	-3.30	R
50	69.0000	80.3667	3.0431	-11.3667	-2.84	R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)

Ploughing De		Mean	SE Mean
0 cm		84.53	1.298
10 - 15 cm		85.67	1.298
15 - 20 cm		85.40	1.298
20 - 25 cm		86.13	1.298
Weed Control			
Cutlass		86.42	1.451
Hoe		86.92	1.451
Knapsack Sprayer		84.50	1.451
No Weed Control		84.00	1.451
Weed Wiper		85.33	1.451
Ploughing De*Weed Control			
0 cm	Cutlass	83.00	2.901
0 cm	Hoe	86.00	2.901
0 cm	Knapsack Sprayer	81.67	2.901
0 cm	No Weed Control	83.33	2.901
0 cm	Weed Wiper	88.67	2.901
10 - 15 cm	Cutlass	88.67	2.901
10 - 15 cm	Hoe	85.00	2.901
10 - 15 cm	Knapsack Sprayer	83.00	2.901
10 - 15 cm	No Weed Control	86.00	2.901
10 - 15 cm	Weed Wiper	85.67	2.901
15 - 20 cm	Cutlass	84.67	2.901
15 - 20 cm	Hoe	88.33	2.901
15 - 20 cm	Knapsack Sprayer	86.67	2.901
15 - 20 cm	No Weed Control	84.00	2.901
15 - 20 cm	Weed Wiper	83.33	2.901
20 - 25 cm	Cutlass	89.33	2.901
20 - 25 cm	Hoe	88.33	2.901
20 - 25 cm	Knapsack Sprayer	86.67	2.901
20 - 25 cm	No Weed Control	82.67	2.901
20 - 25 cm	Weed Wiper	83.67	2.901

16th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

Factor Type Levels Values

```
Block              fixed       3  1, 2, 3
Ploughing Depth    fixed       4  0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control       fixed       5  Cutlass, Hoe, Knapsack Sprayer, No Weed
                                  Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests
Source                        DF   Seq SS  Adj SS  Adj MS     F      P
Block                          2   209.63  209.63  104.82  4.15  0.023
Ploughing Depth                3    20.33   20.33    6.78  0.27  0.848
Weed Control                   4    73.23   73.23   18.31  0.72  0.580
Ploughing Depth*Weed Control  12   221.83  221.83   18.49  0.73  0.712
Error                         38   959.70  959.70   25.26
Total                         59  1484.73

S = 5.02546   R-Sq = 35.36%   R-Sq(adj) = 0.00%

Unusual Observations for Emergence (%)
     Emergence
Obs        (%)      Fit  SE Fit  Residual  St Resid
 25    70.0000  83.1833  3.0431  -13.1833     -3.30 R
 50    69.0000  80.3667  3.0431  -11.3667     -2.84 R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)
Ploughing De                   Mean  SE Mean
0 cm                          84.53    1.298
10 - 15 cm                    85.67    1.298
15 - 20 cm                    85.40    1.298
20 - 25 cm                    86.13    1.298
Weed Control
Cutlass                       86.42    1.451
Hoe                           86.92    1.451
Knapsack Sprayer              84.50    1.451
No Weed Control               84.00    1.451
Weed Wiper                    85.33    1.451
Ploughing De*Weed Control
0 cm          Cutlass         83.00    2.901
0 cm          Hoe             86.00    2.901
0 cm          Knapsack Sprayer 81.67   2.901
0 cm          No Weed Control 83.33    2.901
0 cm          Weed Wiper      88.67    2.901
10 - 15 cm    Cutlass         88.67    2.901
10 - 15 cm    Hoe             85.00    2.901
10 - 15 cm    Knapsack Sprayer 83.00   2.901
10 - 15 cm    No Weed Control 86.00    2.901
10 - 15 cm    Weed Wiper      85.67    2.901
15 - 20 cm    Cutlass         84.67    2.901
15 - 20 cm    Hoe             88.33    2.901
15 - 20 cm    Knapsack Sprayer 86.67   2.901
15 - 20 cm    No Weed Control 84.00    2.901
15 - 20 cm    Weed Wiper      83.33    2.901
20 - 25 cm    Cutlass         89.33    2.901
20 - 25 cm    Hoe             88.33    2.901
20 - 25 cm    Knapsack Sprayer 86.67   2.901
20 - 25 cm    No Weed Control 82.67    2.901
20 - 25 cm    Weed Wiper      83.67    2.901
```

17th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

```
Factor             Type   Levels  Values
Block              fixed       3  1, 2, 3
Ploughing Depth    fixed       4  0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control       fixed       5  Cutlass, Hoe, Knapsack Sprayer, No Weed
                                  Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests
```

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	209.63	209.63	104.82	4.15	0.023
Ploughing Depth	3	20.33	20.33	6.78	0.27	0.848
Weed Control	4	73.23	73.23	18.31	0.72	0.580
Ploughing Depth*Weed Control	12	221.83	221.83	18.49	0.73	0.712
Error	38	959.70	959.70	25.26		
Total	59	1484.73				

S = 5.02546   R-Sq = 35.36%   R-Sq(adj) = 0.00%

Unusual Observations for Emergence (%)

Obs	Emergence (%)	Fit	SE Fit	Residual	St Resid	
25	70.0000	83.1833	3.0431	-13.1833	-3.30	R
50	69.0000	80.3667	3.0431	-11.3667	-2.84	R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)

Ploughing De		Mean	SE Mean
0 cm		84.53	1.298
10 - 15 cm		85.67	1.298
15 - 20 cm		85.40	1.298
20 - 25 cm		86.13	1.298
Weed Control			
Cutlass		86.42	1.451
Hoe		86.92	1.451
Knapsack Sprayer		84.50	1.451
No Weed Control		84.00	1.451
Weed Wiper		85.33	1.451
Ploughing De*Weed Control			
0 cm	Cutlass	83.00	2.901
0 cm	Hoe	86.00	2.901
0 cm	Knapsack Sprayer	81.67	2.901
0 cm	No Weed Control	83.33	2.901
0 cm	Weed Wiper	88.67	2.901
10 - 15 cm	Cutlass	88.67	2.901
10 - 15 cm	Hoe	85.00	2.901
10 - 15 cm	Knapsack Sprayer	83.00	2.901
10 - 15 cm	No Weed Control	86.00	2.901
10 - 15 cm	Weed Wiper	85.67	2.901
15 - 20 cm	Cutlass	84.67	2.901
15 - 20 cm	Hoe	88.33	2.901
15 - 20 cm	Knapsack Sprayer	86.67	2.901
15 - 20 cm	No Weed Control	84.00	2.901
15 - 20 cm	Weed Wiper	83.33	2.901
20 - 25 cm	Cutlass	89.33	2.901
20 - 25 cm	Hoe	88.33	2.901
20 - 25 cm	Knapsack Sprayer	86.67	2.901
20 - 25 cm	No Weed Control	82.67	2.901
20 - 25 cm	Weed Wiper	83.67	2.901

18th June, 2009.

General Linear Model: Emergence (%) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Emergence (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	209.63	209.63	104.82	4.15	0.023
Ploughing Depth	3	20.33	20.33	6.78	0.27	0.848
Weed Control	4	73.23	73.23	18.31	0.72	0.580
Ploughing Depth*Weed Control	12	221.83	221.83	18.49	0.73	0.712
Error	38	959.70	959.70	25.26		

```
Total                        59  1484.73

S = 5.02546   R-Sq = 35.36%   R-Sq(adj) = 0.00%

Unusual Observations for Emergence (%)
     Emergence
Obs        (%)       Fit  SE Fit  Residual  St Resid
 25    70.0000  83.1833  3.0431  -13.1833     -3.30 R
 50    69.0000  80.3667  3.0431  -11.3667     -2.84 R

R denotes an observation with a large standardized residual.

Least Squares Means for Emergence (%)
Ploughing De                   Mean  SE Mean
0 cm                          84.53    1.298
10 - 15 cm                    85.67    1.298
15 - 20 cm                    85.40    1.298
20 - 25 cm                    86.13    1.298
Weed Control
Cutlass                       86.42    1.451
Hoe                           86.92    1.451
Knapsack Sprayer              84.50    1.451
No Weed Control               84.00    1.451
Weed Wiper                    85.33    1.451
Ploughing De*Weed Control
0 cm         Cutlass          83.00    2.901
0 cm         Hoe              86.00    2.901
0 cm         Knapsack Sprayer 81.67    2.901
0 cm         No Weed Control  83.33    2.901
0 cm         Weed Wiper       88.67    2.901
10 - 15 cm   Cutlass          88.67    2.901
10 - 15 cm   Hoe              85.00    2.901
10 - 15 cm   Knapsack Sprayer 83.00    2.901
10 - 15 cm   No Weed Control  86.00    2.901
10 - 15 cm   Weed Wiper       85.67    2.901
15 - 20 cm   Cutlass          84.67    2.901
15 - 20 cm   Hoe              88.33    2.901
15 - 20 cm   Knapsack Sprayer 86.67    2.901
15 - 20 cm   No Weed Control  84.00    2.901
15 - 20 cm   Weed Wiper       83.33    2.901
20 - 25 cm   Cutlass          89.33    2.901
20 - 25 cm   Hoe              88.33    2.901
20 - 25 cm   Knapsack Sprayer 86.67    2.901
20 - 25 cm   No Weed Control  82.67    2.901
20 - 25 cm   Weed Wiper       83.67    2.901
```

PLANT HEIGHT (cm)

6th June, 2009.

General Linear Model: Plant Height (cm) versus Block, Pl Depth (cm), ...

```
Factor     Type Levels Values
Block     fixed      3 1 2 3
Pl Depth  fixed      4 0 cm       10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con  fixed      5 Cutlass          Hoe              Knapsack Sprayer
                       No Weed Control  Weed Wiper

Analysis of Variance for Plant He, using Adjusted SS for Tests
Source              DF     Seq SS     Adj SS     Adj MS       F      P
Block                2     0.7345     0.7345     0.3673    0.78  0.467
Pl Depth             3     5.6163     5.6163     1.8721    3.96  0.015
Weed Con             4     1.1752     1.1752     0.2938    0.62  0.650
Pl Depth*Weed Con   12     6.8835     6.8835     0.5736    1.21  0.310
Error               38    17.9797    17.9797     0.4731
Total               59    32.3892

Unusual Observations for Plant He
Obs  Plant He       Fit     SE Fit  Residual   St Resid
 22   3.17000   4.76250    0.41652  -1.59250     -2.91R
```

```
 44   3.67000   4.78317     0.41652  -1.11317     -2.03R

R denotes an observation with a large standardized residual.

Least Squares Means for Plant He
  Pl Depth                      Mean   SE Mean
0 cm                           4.863    0.1776
10 - 15 cm                     5.680    0.1776
15 - 20 cm                     5.517    0.1776
20 - 25 cm                     5.345    0.1776
        Weed Con
Cutlass                        5.439    0.1986
Hoe                            5.128    0.1986
Knapsack Sprayer               5.268    0.1986
No Weed Control                5.393    0.1986
Weed Wiper                     5.528    0.1986

  Pl Depth*        Weed Con
0 cm       Cutlass             5.310    0.3971
0 cm       Hoe                 4.607    0.3971
0 cm       Knapsack Sprayer    4.777    0.3971
0 cm       No Weed Control     4.747    0.3971
0 cm       Weed Wiper          4.873    0.3971
10 - 15 cm Cutlass             5.770    0.3971
10 - 15 cm Hoe                 5.057    0.3971
10 - 15 cm Knapsack Sprayer    5.323    0.3971
10 - 15 cm No Weed Control     6.043    0.3971
10 - 15 cm Weed Wiper          6.207    0.3971
15 - 20 cm Cutlass             5.000    0.3971
15 - 20 cm Hoe                 5.577    0.3971
15 - 20 cm Knapsack Sprayer    5.680    0.3971
15 - 20 cm No Weed Control     5.110    0.3971
15 - 20 cm Weed Wiper          6.220    0.3971
20 - 25 cm Cutlass             5.677    0.3971
20 - 25 cm Hoe                 5.270    0.3971
20 - 25 cm Knapsack Sprayer    5.290    0.3971
20 - 25 cm No Weed Control     5.673    0.3971
20 - 25 cm Weed Wiper          4.813    0.3971
```

13th June, 2009.

General Linear Model: Plant Height versus Block, Ploughing De, ...

```
Factor           Type   Levels  Values
Block            fixed       3  1, 2, 3
Ploughing Depth  fixed       4  0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control     fixed       5  Cutlass, Hoe, Knapsack Sprayer, No Weed
                                Control, Weed Wiper

Analysis of Variance for Plant Height (cm), using Adjusted SS for Tests
Source                        DF   Seq SS   Adj SS   Adj MS      F      P
Block                          2   67.497   67.497   33.748  22.29  0.000
Ploughing Depth                3   60.665   60.665   20.222  13.36  0.000
Weed Control                   4    8.704    8.704    2.176   1.44  0.241
Ploughing Depth*Weed Control  12   40.844   40.844    3.404   2.25  0.029
Error                         38   57.535   57.535    1.514
Total                         59  235.243

S = 1.23048   R-Sq = 75.54%   R-Sq(adj) = 62.03%

Unusual Observations for Plant Height (cm)
          Plant
Obs  Height (cm)      Fit  SE Fit  Residual  St Resid
  6      20.5300  17.8827  0.7451    2.6473      2.70 R
 26      15.5500  17.7897  0.7451   -2.2397     -2.29 R
 29      20.6700  17.8697  0.7451    2.8003      2.86 R
 56      15.9000  13.5243  0.7451    2.3757      2.43 R

R denotes an observation with a large standardized residual.
```

Least Squares Means for Plant Height (cm)

Ploughing De		Mean	SE Mean
0 cm		13.53	0.3177
10 - 15 cm		16.08	0.3177
15 - 20 cm		15.88	0.3177
20 - 25 cm		14.95	0.3177
Weed Control			
Cutlass		15.82	0.3552
Hoe		14.75	0.3552
Knapsack Sprayer		14.81	0.3552
No Weed Control		15.11	0.3552
Weed Wiper		15.06	0.3552
Ploughing De*Weed Control			
0 cm	Cutlass	14.91	0.7104
0 cm	Hoe	13.06	0.7104
0 cm	Knapsack Sprayer	13.24	0.7104
0 cm	No Weed Control	12.71	0.7104
0 cm	Weed Wiper	13.73	0.7104
10 - 15 cm	Cutlass	16.92	0.7104
10 - 15 cm	Hoe	13.96	0.7104
10 - 15 cm	Knapsack Sprayer	15.25	0.7104
10 - 15 cm	No Weed Control	17.09	0.7104
10 - 15 cm	Weed Wiper	17.17	0.7104
15 - 20 cm	Cutlass	15.41	0.7104
15 - 20 cm	Hoe	16.89	0.7104
15 - 20 cm	Knapsack Sprayer	16.73	0.7104
15 - 20 cm	No Weed Control	15.61	0.7104
15 - 20 cm	Weed Wiper	14.76	0.7104
20 - 25 cm	Cutlass	16.03	0.7104
20 - 25 cm	Hoe	15.10	0.7104
20 - 25 cm	Knapsack Sprayer	14.01	0.7104
20 - 25 cm	No Weed Control	15.02	0.7104
20 - 25 cm	Weed Wiper	14.58	0.7104

20th June, 2009.

General Linear Model: Plant Height versus Block, Ploughing De, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Plant Height (cm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	503.201	503.201	251.600	30.33	0.000
Ploughing Depth	3	175.236	175.236	58.412	7.04	0.001
Weed Control	4	9.701	9.701	2.425	0.29	0.881
Ploughing Depth*Weed Control	12	118.340	118.340	9.862	1.19	0.326
Error	38	315.263	315.263	8.296		
Total	59	1121.741				

S = 2.88034   R-Sq = 71.90%   R-Sq(adj) = 56.36%

Unusual Observations for Plant Height (cm)

Obs	Plant Height (cm)	Fit	SE Fit	Residual	St Resid	
9	24.1700	29.0702	1.7441	-4.9002	-2.14	R
25	19.7000	25.2790	1.7441	-5.5790	-2.43	R
29	38.9500	31.1857	1.7441	7.7643	3.39	R
39	21.7000	26.6023	1.7441	-4.9023	-2.14	R

R denotes an observation with a large standardized residual.

Least Squares Means for Plant Height (cm)

Ploughing De	Mean	SE Mean
0 cm	22.27	0.7437

10 - 15 cm		25.74	0.7437
15 - 20 cm		26.51	0.7437
20 - 25 cm		23.43	0.7437
Weed Control			
Cutlass		25.01	0.8315
Hoe		24.25	0.8315
Knapsack Sprayer		23.86	0.8315
No Weed Control		24.57	0.8315
Weed Wiper		24.75	0.8315
Ploughing De*Weed Control			
0 cm	Cutlass	23.27	1.6630
0 cm	Hoe	22.57	1.6630
0 cm	Knapsack Sprayer	22.27	1.6630
0 cm	No Weed Control	19.98	1.6630
0 cm	Weed Wiper	23.27	1.6630
10 - 15 cm	Cutlass	27.18	1.6630
10 - 15 cm	Hoe	22.80	1.6630
10 - 15 cm	Knapsack Sprayer	23.68	1.6630
10 - 15 cm	No Weed Control	26.87	1.6630
10 - 15 cm	Weed Wiper	28.17	1.6630
15 - 20 cm	Cutlass	25.63	1.6630
15 - 20 cm	Hoe	27.89	1.6630
15 - 20 cm	Knapsack Sprayer	26.84	1.6630
15 - 20 cm	No Weed Control	28.21	1.6630
15 - 20 cm	Weed Wiper	23.97	1.6630
20 - 25 cm	Cutlass	23.98	1.6630
20 - 25 cm	Hoe	23.72	1.6630
20 - 25 cm	Knapsack Sprayer	22.63	1.6630
20 - 25 cm	No Weed Control	23.23	1.6630
20 - 25 cm	Weed Wiper	23.59	1.6630

27h June, 2009.

General Linear Model: Plant Height versus Block, Ploughing De, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Plant Height (cm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	1832.42	1832.42	916.21	39.91	0.000
Ploughing Depth	3	1619.20	1619.20	539.73	23.51	0.000
Weed Control	4	119.96	119.96	29.99	1.31	0.285
Ploughing Depth*Weed Control	12	245.95	245.95	20.50	0.89	0.562
Error	38	872.35	872.35	22.96		
Total	59	4689.88				

S = 4.79130   R-Sq = 81.40%   R-Sq(adj) = 71.12%

Unusual Observations for Plant Height (cm)

Obs	Plant Height (cm)	Fit	SE Fit	Residual	St Resid	
25	28.2000	39.1890	2.9013	-10.9890	-2.88	R
29	66.5200	56.6423	2.9013	9.8777	2.59	R
44	35.1500	27.5048	2.9013	7.6452	2.01	R

R denotes an observation with a large standardized residual.

Least Squares Means for Plant Height (cm)

Ploughing De	Mean	SE Mean
0 cm	34.28	1.237
10 - 15 cm	45.50	1.237
15 - 20 cm	48.06	1.237
20 - 25 cm	41.84	1.237
Weed Control		
Cutlass	41.89	1.383
Hoe	42.48	1.383

Knapsack Sprayer		40.40	1.383
No Weed Control		42.54	1.383
Weed Wiper		44.79	1.383
Ploughing De*Weed Control			
0 cm	Cutlass	35.02	2.766
0 cm	Hoe	35.50	2.766
0 cm	Knapsack Sprayer	34.13	2.766
0 cm	No Weed Control	31.55	2.766
0 cm	Weed Wiper	35.19	2.766
10 - 15 cm	Cutlass	46.10	2.766
10 - 15 cm	Hoe	41.78	2.766
10 - 15 cm	Knapsack Sprayer	42.84	2.766
10 - 15 cm	No Weed Control	45.22	2.766
10 - 15 cm	Weed Wiper	51.58	2.766
15 - 20 cm	Cutlass	44.57	2.766
15 - 20 cm	Hoe	51.89	2.766
15 - 20 cm	Knapsack Sprayer	45.15	2.766
15 - 20 cm	No Weed Control	48.87	2.766
15 - 20 cm	Weed Wiper	49.82	2.766
20 - 25 cm	Cutlass	41.88	2.766
20 - 25 cm	Hoe	40.77	2.766
20 - 25 cm	Knapsack Sprayer	39.49	2.766
20 - 25 cm	No Weed Control	44.49	2.766
20 - 25 cm	Weed Wiper	42.58	2.766

4th July, 2009.

General Linear Model: Plant Height versus Block, Ploughing De, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Plant Height (cm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	4257.16	4257.16	2128.58	40.99	0.000
Ploughing Depth	3	3686.39	3686.39	1228.80	23.66	0.000
Weed Control	4	97.75	97.75	24.44	0.47	0.757
Ploughing Depth*Weed Control	12	339.52	339.52	28.29	0.54	0.871
Error	38	1973.45	1973.45	51.93		
Total	59	10354.28				

S = 7.20646   R-Sq = 80.94%   R-Sq(adj) = 70.41%

Unusual Observations for Plant Height (cm)

Obs	Plant Height (cm)	Fit	SE Fit	Residual	St Resid	
25	38.1200	51.5505	4.3637	-13.4305	-2.34	R
28	84.7800	72.8572	4.3637	11.9228	2.08	R

R denotes an observation with a large standardized residual.

Least Squares Means for Plant Height (cm)

Ploughing De		Mean	SE Mean
0 cm		48.59	1.861
10 - 15 cm		65.44	1.861
15 - 20 cm		69.13	1.861
20 - 25 cm		63.85	1.861
Weed Control			
Cutlass		62.46	2.080
Hoe		61.83	2.080
Knapsack Sprayer		59.62	2.080
No Weed Control		61.40	2.080
Weed Wiper		63.47	2.080
Ploughing De*Weed Control			
0 cm	Cutlass	50.75	4.161
0 cm	Hoe	51.26	4.161

0 cm	Knapsack Sprayer	45.45	4.161
0 cm	No Weed Control	45.75	4.161
0 cm	Weed Wiper	49.73	4.161
10 - 15 cm	Cutlass	66.75	4.161
10 - 15 cm	Hoe	64.55	4.161
10 - 15 cm	Knapsack Sprayer	63.51	4.161
10 - 15 cm	No Weed Control	60.83	4.161
10 - 15 cm	Weed Wiper	71.58	4.161
15 - 20 cm	Cutlass	67.37	4.161
15 - 20 cm	Hoe	70.88	4.161
15 - 20 cm	Knapsack Sprayer	67.51	4.161
15 - 20 cm	No Weed Control	72.77	4.161
15 - 20 cm	Weed Wiper	67.12	4.161
20 - 25 cm	Cutlass	64.95	4.161
20 - 25 cm	Hoe	60.62	4.161
20 - 25 cm	Knapsack Sprayer	62.01	4.161
20 - 25 cm	No Weed Control	66.23	4.161
20 - 25 cm	Weed Wiper	65.46	4.161

11th July, 2009.

General Linear Model: Plant Height versus Block, Ploughing De, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Plant Height (cm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	9501.8	9501.8	4750.9	37.96	0.000
Ploughing Depth	3	11417.2	11417.2	3805.7	30.41	0.000
Weed Control	4	115.2	115.2	28.8	0.23	0.920
Ploughing Depth*Weed Control	12	671.3	671.3	55.9	0.45	0.933
Error	38	4755.4	4755.4	125.1		
Total	59	26460.9				

S = 11.1867   R-Sq = 82.03%   R-Sq(adj) = 72.10%

Unusual Observations for Plant Height (cm)

Obs	Plant Height (cm)	Fit	SE Fit	Residual	St Resid
44	61.980	42.222	6.774	19.758	2.22 R
45	57.030	36.702	6.774	20.328	2.28 R

R denotes an observation with a large standardized residual.

Least Squares Means for Plant Height (cm)

Ploughing De		Mean	SE Mean
0 cm		57.92	2.888
10 - 15 cm		88.21	2.888
15 - 20 cm		92.49	2.888
20 - 25 cm		87.78	2.888
Weed Control			
Cutlass		82.81	3.229
Hoe		81.84	3.229
Knapsack Sprayer		79.46	3.229
No Weed Control		80.67	3.229
Weed Wiper		83.23	3.229
Ploughing De*Weed Control			
0 cm	Cutlass	59.34	6.459
0 cm	Hoe	62.36	6.459
0 cm	Knapsack Sprayer	54.49	6.459
0 cm	No Weed Control	53.41	6.459
0 cm	Weed Wiper	60.01	6.459
10 - 15 cm	Cutlass	90.31	6.459
10 - 15 cm	Hoe	89.76	6.459

10 - 15 cm	Knapsack Sprayer	83.91	6.459
10 - 15 cm	No Weed Control	84.33	6.459
10 - 15 cm	Weed Wiper	92.72	6.459
15 - 20 cm	Cutlass	89.49	6.459
15 - 20 cm	Hoe	93.92	6.459
15 - 20 cm	Knapsack Sprayer	90.81	6.459
15 - 20 cm	No Weed Control	99.06	6.459
15 - 20 cm	Weed Wiper	89.19	6.459
20 - 25 cm	Cutlass	92.08	6.459
20 - 25 cm	Hoe	81.30	6.459
20 - 25 cm	Knapsack Sprayer	88.65	6.459
20 - 25 cm	No Weed Control	85.86	6.459
20 - 25 cm	Weed Wiper	90.99	6.459

18th July, 2009.

General Linear Model: Plant Height versus Block, Ploughing De, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Plant Height (cm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	16040.0	16040.0	8020.0	35.19	0.000
Ploughing Depth	3	23416.4	23416.4	7805.5	34.25	0.000
Weed Control	4	245.3	245.3	61.3	0.27	0.896
Ploughing Depth*Weed Control	12	1632.3	1632.3	136.0	0.60	0.831
Error	38	8659.8	8659.8	227.9		
Total	59	49993.8				

S = 15.0960   R-Sq = 82.68%   R-Sq(adj) = 73.11%

Unusual Observations for Plant Height (cm)

Obs	Plant Height (cm)	Fit	SE Fit	Residual	St Resid
28	150.850	125.546	9.141	25.304	2.11 R
44	70.550	43.541	9.141	27.009	2.25 R
45	68.220	41.064	9.141	27.156	2.26 R

R denotes an observation with a large standardized residual.

Least Squares Means for Plant Height (cm)

Ploughing De		Mean	SE Mean
0 cm		65.90	3.898
10 - 15 cm		108.46	3.898
15 - 20 cm		113.88	3.898
20 - 25 cm		111.58	3.898
Weed Control			
Cutlass		102.20	4.358
Hoe		99.54	4.358
Knapsack Sprayer		96.70	4.358
No Weed Control		99.33	4.358
Weed Wiper		102.02	4.358
Ploughing De*Weed Control			
0 cm	Cutlass	65.05	8.716
0 cm	Hoe	73.23	8.716
0 cm	Knapsack Sprayer	64.11	8.716
0 cm	No Weed Control	60.54	8.716
0 cm	Weed Wiper	66.58	8.716
10 - 15 cm	Cutlass	112.36	8.716
10 - 15 cm	Hoe	114.06	8.716
10 - 15 cm	Knapsack Sprayer	100.09	8.716
10 - 15 cm	No Weed Control	100.21	8.716
10 - 15 cm	Weed Wiper	115.59	8.716
15 - 20 cm	Cutlass	115.64	8.716
15 - 20 cm	Hoe	110.96	8.716

15 - 20 cm	Knapsack Sprayer	112.66	8.716
15 - 20 cm	No Weed Control	121.67	8.716
15 - 20 cm	Weed Wiper	108.50	8.716
20 - 25 cm	Cutlass	115.74	8.716
20 - 25 cm	Hoe	99.92	8.716
20 - 25 cm	Knapsack Sprayer	109.94	8.716
20 - 25 cm	No Weed Control	114.88	8.716
20 - 25 cm	Weed Wiper	117.41	8.716

25th July, 2009.

General Linear Model: Plant Height versus Block, Ploughing De, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Plant Height (cm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	25812.7	25812.7	12906.3	28.49	0.000
Ploughing Depth	3	38141.6	38141.6	12713.9	28.06	0.000
Weed Control	4	1112.0	1112.0	278.0	0.61	0.655
Ploughing Depth*Weed Control	12	2620.3	2620.3	218.4	0.48	0.913
Error	38	17216.6	17216.6	453.1		
Total	59	84903.1				

S = 21.2854   R-Sq = 79.72%   R-Sq(adj) = 68.52%

Unusual Observations for Plant Height (cm)

Obs	Plant Height (cm)	Fit	SE Fit	Residual	St Resid
44	87.700	50.183	12.889	37.517	2.21 R
45	84.730	43.783	12.889	40.947	2.42 R

R denotes an observation with a large standardized residual.

Least Squares Means for Plant Height (cm)

Ploughing De		Mean	SE Mean
0 cm		77.47	5.496
10 - 15 cm		132.06	5.496
15 - 20 cm		137.47	5.496
20 - 25 cm		136.94	5.496
Weed Control			
Cutlass		125.01	6.145
Hoe		123.49	6.145
Knapsack Sprayer		112.94	6.145
No Weed Control		120.28	6.145
Weed Wiper		123.19	6.145
Ploughing De*Weed Control			
0 cm	Cutlass	79.52	12.289
0 cm	Hoe	86.86	12.289
0 cm	Knapsack Sprayer	72.96	12.289
0 cm	No Weed Control	68.64	12.289
0 cm	Weed Wiper	79.36	12.289
10 - 15 cm	Cutlass	138.37	12.289
10 - 15 cm	Hoe	142.18	12.289
10 - 15 cm	Knapsack Sprayer	117.91	12.289
10 - 15 cm	No Weed Control	126.61	12.289
10 - 15 cm	Weed Wiper	135.21	12.289
15 - 20 cm	Cutlass	137.25	12.289
15 - 20 cm	Hoe	143.38	12.289
15 - 20 cm	Knapsack Sprayer	131.15	12.289
15 - 20 cm	No Weed Control	145.13	12.289
15 - 20 cm	Weed Wiper	130.42	12.289
20 - 25 cm	Cutlass	144.92	12.289
20 - 25 cm	Hoe	121.55	12.289

20 - 25 cm	Knapsack Sprayer	129.73	12.289
20 - 25 cm	No Weed Control	140.74	12.289
20 - 25 cm	Weed Wiper	147.77	12.289

1st August, 2009.

General Linear Model: Plant Height versus Block, Ploughing De, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Plant Height (cm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	30065.3	30065.3	15032.6	23.01	0.000
Ploughing Depth	3	59609.8	59609.8	19869.9	30.42	0.000
Weed Control	4	4619.1	4619.1	1154.8	1.77	0.156
Ploughing Depth*Weed Control	12	5574.5	5574.5	464.5	0.71	0.731
Error	38	24825.0	24825.0	653.3		
Total	59	124693.7				

S = 25.5595   R-Sq = 80.09%   R-Sq(adj) = 69.09%

Unusual Observations for Plant Height (cm)

Obs	Plant Height (cm)	Fit	SE Fit	Residual	St Resid	
4	74.830	120.650	15.477	-45.820	-2.25	R
44	129.070	75.410	15.477	53.660	2.64	R
45	99.370	50.553	15.477	48.817	2.40	R

R denotes an observation with a large standardized residual.

Least Squares Means for Plant Height (cm)

Ploughing De		Mean	SE Mean
0 cm		96.51	6.599
10 - 15 cm		165.25	6.599
15 - 20 cm		171.76	6.599
20 - 25 cm		170.25	6.599
Weed Control			
Cutlass		158.57	7.378
Hoe		158.24	7.378
Knapsack Sprayer		135.10	7.378
No Weed Control		148.07	7.378
Weed Wiper		154.72	7.378
Ploughing De*Weed Control			
0 cm	Cutlass	106.45	14.757
0 cm	Hoe	111.08	14.757
0 cm	Knapsack Sprayer	82.12	14.757
0 cm	No Weed Control	75.92	14.757
0 cm	Weed Wiper	106.97	14.757
10 - 15 cm	Cutlass	177.19	14.757
10 - 15 cm	Hoe	181.55	14.757
10 - 15 cm	Knapsack Sprayer	142.20	14.757
10 - 15 cm	No Weed Control	156.92	14.757
10 - 15 cm	Weed Wiper	168.40	14.757
15 - 20 cm	Cutlass	171.94	14.757
15 - 20 cm	Hoe	184.37	14.757
15 - 20 cm	Knapsack Sprayer	152.23	14.757
15 - 20 cm	No Weed Control	187.92	14.757
15 - 20 cm	Weed Wiper	162.35	14.757
20 - 25 cm	Cutlass	178.70	14.757
20 - 25 cm	Hoe	155.97	14.757
20 - 25 cm	Knapsack Sprayer	163.87	14.757
20 - 25 cm	No Weed Control	171.53	14.757
20 - 25 cm	Weed Wiper	181.17	14.757

8th August, 2009.

General Linear Model: Plant Height versus Block, Ploughing De, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Plant Height (cm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	24353.6	24353.6	12176.8	18.97	0.000
Ploughing Depth	3	60194.0	60194.0	20064.7	31.26	0.000
Weed Control	4	5659.5	5659.5	1414.9	2.20	0.087
Ploughing Depth*Weed Control	12	5592.7	5592.7	466.1	0.73	0.717
Error	38	24387.0	24387.0	641.8		
Total	59	120186.8				

S = 25.3330 R-Sq = 79.71% R-Sq(adj) = 68.50%

Unusual Observations for Plant Height (cm)

Obs	Plant Height (cm)	Fit	SE Fit	Residual	St Resid	
4	79.180	127.033	15.340	-47.852	-2.37	R
44	142.270	88.531	15.340	53.739	2.67	R
45	108.950	61.008	15.340	47.942	2.38	R
53	112.750	158.344	15.340	-45.594	-2.26	R

R denotes an observation with a large standardized residual.

Least Squares Means for Plant Height (cm)

Ploughing De		Mean	SE Mean
0 cm		104.98	6.541
10 - 15 cm		173.24	6.541
15 - 20 cm		180.50	6.541
20 - 25 cm		179.78	6.541
Weed Control			
Cutlass		170.53	7.313
Hoe		167.23	7.313
Knapsack Sprayer		143.04	7.313
No Weed Control		155.68	7.313
Weed Wiper		161.64	7.313
Ploughing De*Weed Control			
0 cm	Cutlass	116.40	14.626
0 cm	Hoe	115.14	14.626
0 cm	Knapsack Sprayer	89.17	14.626
0 cm	No Weed Control	87.51	14.626
0 cm	Weed Wiper	116.69	14.626
10 - 15 cm	Cutlass	188.12	14.626
10 - 15 cm	Hoe	192.47	14.626
10 - 15 cm	Knapsack Sprayer	151.57	14.626
10 - 15 cm	No Weed Control	158.14	14.626
10 - 15 cm	Weed Wiper	175.93	14.626
15 - 20 cm	Cutlass	186.51	14.626
15 - 20 cm	Hoe	192.09	14.626
15 - 20 cm	Knapsack Sprayer	160.18	14.626
15 - 20 cm	No Weed Control	198.42	14.626
15 - 20 cm	Weed Wiper	165.29	14.626
20 - 25 cm	Cutlass	191.11	14.626
20 - 25 cm	Hoe	169.23	14.626
20 - 25 cm	Knapsack Sprayer	171.23	14.626
20 - 25 cm	No Weed Control	178.65	14.626
20 - 25 cm	Weed Wiper	188.67	14.626

STEM GIRTH (mm)

6th June, 2009.

General Linear Model: Girth Stem (mm) versus Block, Ploughing Depth, ...

Factor Type Levels Values

Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Girth Stem (mm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	2.6043	2.6043	1.3022	8.44	0.001
Ploughing Depth	3	13.8725	13.8725	4.6242	29.97	0.000
Weed Control	4	0.6240	0.6240	0.1560	1.01	0.414
Ploughing Depth*Weed Control	12	1.8267	1.8267	0.1522	0.99	0.479
Error	38	5.8623	5.8623	0.1543		
Total	59	24.7898				

S = 0.392775   R-Sq = 76.35%   R-Sq(adj) = 63.28%

Unusual Observations for Girth Stem (mm)

Obs	Girth Stem (mm)	Fit	SE Fit	Residual	St Resid
14	12.2000	11.2550	0.2378	0.9450	3.02 R

R denotes an observation with a large standardized residual.

Least Squares Means for Girth Stem (mm)

Ploughing De		Mean	SE Mean
0 cm		9.173	0.1014
10 - 15 cm		10.113	0.1014
15 - 20 cm		10.487	0.1014
20 - 25 cm		10.033	0.1014
Weed Control			
Cutlass		9.983	0.1134
Hoe		9.933	0.1134
Knapsack Sprayer		9.767	0.1134
No Weed Control		10.067	0.1134
Weed Wiper		10.008	0.1134
Ploughing De*Weed Control			
0 cm	Cutlass	9.400	0.2268
0 cm	Hoe	9.133	0.2268
0 cm	Knapsack Sprayer	8.967	0.2268
0 cm	No Weed Control	9.167	0.2268
0 cm	Weed Wiper	9.200	0.2268
10 - 15 cm	Cutlass	10.167	0.2268
10 - 15 cm	Hoe	10.000	0.2268
10 - 15 cm	Knapsack Sprayer	9.933	0.2268
10 - 15 cm	No Weed Control	10.433	0.2268
10 - 15 cm	Weed Wiper	10.033	0.2268
15 - 20 cm	Cutlass	10.167	0.2268
15 - 20 cm	Hoe	10.600	0.2268
15 - 20 cm	Knapsack Sprayer	10.333	0.2268
15 - 20 cm	No Weed Control	10.367	0.2268
15 - 20 cm	Weed Wiper	10.967	0.2268
20 - 25 cm	Cutlass	10.200	0.2268
20 - 25 cm	Hoe	10.000	0.2268
20 - 25 cm	Knapsack Sprayer	9.833	0.2268
20 - 25 cm	No Weed Control	10.300	0.2268
20 - 25 cm	Weed Wiper	9.833	0.2268

13th June, 2009.

General Linear Model: Girth Stem (mm) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Girth Stem (mm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P

Block	2	53.206	53.206	26.603	20.04	0.000
Ploughing Depth	3	95.327	95.327	31.776	23.93	0.000
Weed Control	4	2.346	2.346	0.586	0.44	0.778
Ploughing Depth*Weed Control	12	7.937	7.937	0.661	0.50	0.903
Error	38	50.454	50.454	1.328		
Total	59	209.270				

S = 1.15227   R-Sq = 75.89%   R-Sq(adj) = 62.57%

Unusual Observations for Girth Stem (mm)

Obs	Girth Stem (mm)	Fit	SE Fit	Residual	St Resid	
14	17.8000	15.6867	0.6977	2.1133	2.30	R
23	11.0000	12.8783	0.6977	-1.8783	-2.05	R
29	19.3000	16.6117	0.6977	2.6883	2.93	R

R denotes an observation with a large standardized residual.

Least Squares Means for Girth Stem (mm)

Ploughing De		Mean	SE Mean
0 cm		12.20	0.2975
10 - 15 cm		15.19	0.2975
15 - 20 cm		15.36	0.2975
20 - 25 cm		14.45	0.2975
Weed Control			
Cutlass		14.39	0.3326
Hoe		14.52	0.3326
Knapsack Sprayer		13.94	0.3326
No Weed Control		14.27	0.3326
Weed Wiper		14.38	0.3326
Ploughing De*Weed Control			
0 cm	Cutlass	12.20	0.6653
0 cm	Hoe	12.57	0.6653
0 cm	Knapsack Sprayer	12.07	0.6653
0 cm	No Weed Control	11.77	0.6653
0 cm	Weed Wiper	12.40	0.6653
10 - 15 cm	Cutlass	15.43	0.6653
10 - 15 cm	Hoe	14.67	0.6653
10 - 15 cm	Knapsack Sprayer	14.33	0.6653
10 - 15 cm	No Weed Control	15.60	0.6653
10 - 15 cm	Weed Wiper	15.93	0.6653
15 - 20 cm	Cutlass	15.20	0.6653
15 - 20 cm	Hoe	16.23	0.6653
15 - 20 cm	Knapsack Sprayer	14.97	0.6653
15 - 20 cm	No Weed Control	15.37	0.6653
15 - 20 cm	Weed Wiper	15.03	0.6653
20 - 25 cm	Cutlass	14.73	0.6653
20 - 25 cm	Hoe	14.63	0.6653
20 - 25 cm	Knapsack Sprayer	14.40	0.6653
20 - 25 cm	No Weed Control	14.33	0.6653
20 - 25 cm	Weed Wiper	14.17	0.6653

20th June, 2009.

General Linear Model: Girth Stem (mm) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Girth Stem (mm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	368.704	368.704	184.352	33.15	0.000
Ploughing Depth	3	437.393	437.392	145.797	26.22	0.000
Weed Control	4	9.957	9.957	2.489	0.45	0.773
Ploughing Depth*Weed Control	12	51.427	51.427	4.286	0.77	0.676
Error	38	211.309	211.309	5.561		

Total	59	1078.790

S = 2.35813   R-Sq = 80.41%   R-Sq(adj) = 69.59%

Unusual Observations for Girth Stem (mm)

Obs	Girth Stem (mm)	Fit	SE Fit	Residual	St Resid
23	14.2000	19.1550	1.4279	-4.9550	-2.64 R
29	32.3000	27.3217	1.4279	4.9783	2.65 R

R denotes an observation with a large standardized residual.

Least Squares Means for Girth Stem (mm)

Ploughing De		Mean	SE Mean
0 cm		16.90	0.6089
10 - 15 cm		22.99	0.6089
15 - 20 cm		23.54	0.6089
20 - 25 cm		22.78	0.6089
Weed Control			
Cutlass		21.53	0.6807
Hoe		21.48	0.6807
Knapsack Sprayer		20.85	0.6807
No Weed Control		22.05	0.6807
Weed Wiper		21.84	0.6807
Ploughing De*Weed Control			
0 cm	Cutlass	16.77	1.3615
0 cm	Hoe	18.17	1.3615
0 cm	Knapsack Sprayer	16.53	1.3615
0 cm	No Weed Control	15.70	1.3615
0 cm	Weed Wiper	17.33	1.3615
10 - 15 cm	Cutlass	23.50	1.3615
10 - 15 cm	Hoe	20.83	1.3615
10 - 15 cm	Knapsack Sprayer	21.63	1.3615
10 - 15 cm	No Weed Control	24.03	1.3615
10 - 15 cm	Weed Wiper	24.93	1.3615
15 - 20 cm	Cutlass	23.10	1.3615
15 - 20 cm	Hoe	24.27	1.3615
15 - 20 cm	Knapsack Sprayer	22.70	1.3615
15 - 20 cm	No Weed Control	25.13	1.3615
15 - 20 cm	Weed Wiper	22.50	1.3615
20 - 25 cm	Cutlass	22.77	1.3615
20 - 25 cm	Hoe	22.67	1.3615
20 - 25 cm	Knapsack Sprayer	22.53	1.3615
20 - 25 cm	No Weed Control	23.33	1.3615
20 - 25 cm	Weed Wiper	22.60	1.3615

27^{h} June, 2009.

General Linear Model: Girth Stem (mm) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Girth Stem (mm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	1429.23	1429.22	714.61	46.72	0.000
Ploughing Depth	3	1769.49	1769.49	589.83	38.57	0.000
Weed Control	4	39.36	39.36	9.84	0.64	0.635
Ploughing Depth*Weed Control	12	146.90	146.90	12.24	0.80	0.648
Error	38	581.17	581.17	15.29		
Total	59	3966.15				

S = 3.91076   R-Sq = 85.35%   R-Sq(adj) = 77.25%

Unusual Observations for Girth Stem (mm)
        Girth

Obs	Stem (mm)	Fit	SE Fit	Residual	St Resid	
25	19.3000	26.1917	2.3681	-6.8917	-2.21	R
28	46.5000	39.8250	2.3681	6.6750	2.14	R
29	49.3000	41.9917	2.3681	7.3083	2.35	R

R denotes an observation with a large standardized residual.

Least Squares Means for Girth Stem (mm)

Ploughing De		Mean	SE Mean
0 cm		22.20	1.010
10 - 15 cm		34.29	1.010
15 - 20 cm		36.02	1.010
20 - 25 cm		33.31	1.010
Weed Control			
Cutlass		31.35	1.129
Hoe		31.48	1.129
Knapsack Sprayer		30.01	1.129
No Weed Control		32.18	1.129
Weed Wiper		32.26	1.129
Ploughing De*Weed Control			
0 cm	Cutlass	21.77	2.258
0 cm	Hoe	24.53	2.258
0 cm	Knapsack Sprayer	21.77	2.258
0 cm	No Weed Control	19.83	2.258
0 cm	Weed Wiper	23.10	2.258
10 - 15 cm	Cutlass	35.40	2.258
10 - 15 cm	Hoe	31.57	2.258
10 - 15 cm	Knapsack Sprayer	32.03	2.258
10 - 15 cm	No Weed Control	34.87	2.258
10 - 15 cm	Weed Wiper	37.57	2.258
15 - 20 cm	Cutlass	34.73	2.258
15 - 20 cm	Hoe	37.73	2.258
15 - 20 cm	Knapsack Sprayer	33.90	2.258
15 - 20 cm	No Weed Control	38.97	2.258
15 - 20 cm	Weed Wiper	34.77	2.258
20 - 25 cm	Cutlass	33.50	2.258
20 - 25 cm	Hoe	32.07	2.258
20 - 25 cm	Knapsack Sprayer	32.33	2.258
20 - 25 cm	No Weed Control	35.07	2.258
20 - 25 cm	Weed Wiper	33.60	2.258

4th July, 2009.

General Linear Model: Girth Stem (mm) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Girth Stem (mm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	2466.01	2466.01	1233.00	43.55	0.000
Ploughing Depth	3	3880.00	3880.00	1293.33	45.68	0.000
Weed Control	4	72.94	72.94	18.24	0.64	0.634
Ploughing Depth*Weed Control	12	214.94	214.94	17.91	0.63	0.801
Error	38	1075.82	1075.82	28.31		
Total	59	7709.71				

S = 5.32083   R-Sq = 86.05%   R-Sq(adj) = 78.33%

Unusual Observations for Girth Stem (mm)

Obs	Girth Stem (mm)	Fit	SE Fit	Residual	St Resid	
28	60.8000	52.1250	3.2219	8.6750	2.05	R
44	28.5000	19.2583	3.2219	9.2417	2.18	R

R denotes an observation with a large standardized residual.

Least Squares Means for Girth Stem (mm)

Ploughing De		Mean	SE Mean
0 cm		26.93	1.374
10 - 15 cm		44.19	1.374
15 - 20 cm		47.13	1.374
20 - 25 cm		44.63	1.374
Weed Control			
Cutlass		41.37	1.536
Hoe		40.46	1.536
Knapsack Sprayer		38.73	1.536
No Weed Control		41.08	1.536
Weed Wiper		41.95	1.536
Ploughing De*Weed Control			
0 cm	Cutlass	27.23	3.072
0 cm	Hoe	30.67	3.072
0 cm	Knapsack Sprayer	24.57	3.072
0 cm	No Weed Control	23.90	3.072
0 cm	Weed Wiper	28.27	3.072
10 - 15 cm	Cutlass	46.73	3.072
10 - 15 cm	Hoe	42.77	3.072
10 - 15 cm	Knapsack Sprayer	41.17	3.072
10 - 15 cm	No Weed Control	42.93	3.072
10 - 15 cm	Weed Wiper	47.33	3.072
15 - 20 cm	Cutlass	46.50	3.072
15 - 20 cm	Hoe	47.03	3.072
15 - 20 cm	Knapsack Sprayer	44.67	3.072
15 - 20 cm	No Weed Control	50.83	3.072
15 - 20 cm	Weed Wiper	46.63	3.072
20 - 25 cm	Cutlass	45.00	3.072
20 - 25 cm	Hoe	41.37	3.072
20 - 25 cm	Knapsack Sprayer	44.53	3.072
20 - 25 cm	No Weed Control	46.67	3.072
20 - 25 cm	Weed Wiper	45.57	3.072

11th July, 2009.

General Linear Model: Girth Stem (mm) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Girth Stem (mm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	2061.12	2061.12	1030.56	31.98	0.000
Ploughing Depth	3	5084.12	5084.12	1694.71	52.60	0.000
Weed Control	4	83.36	83.36	20.84	0.65	0.633
Ploughing Depth*Weed Control	12	289.27	289.27	24.11	0.75	0.697
Error	38	1224.40	1224.40	32.22		
Total	59	8742.27				

S = 5.67635   R-Sq = 85.99%   R-Sq(adj) = 78.25%

Unusual Observations for Girth Stem (mm)

Obs	Girth Stem (mm)	Fit	SE Fit	Residual	St Resid
44	34.7000	23.6950	3.4372	11.0050	2.44 R
45	29.7000	19.9950	3.4372	9.7050	2.15 R

R denotes an observation with a large standardized residual.

Least Squares Means for Girth Stem (mm)

Ploughing De	Mean	SE Mean
0 cm	30.38	1.466
10 - 15 cm	50.45	1.466
15 - 20 cm	52.35	1.466

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20 - 25 cm                    51.93    1.466
Weed Control
Cutlass                       46.58    1.639
Hoe                           45.93    1.639
Knapsack Sprayer              44.24    1.639
No Weed Control               46.85    1.639
Weed Wiper                    47.78    1.639
Ploughing De*Weed Control
0 cm          Cutlass         29.93    3.277
0 cm          Hoe             34.83    3.277
0 cm          Knapsack Sprayer  28.17    3.277
0 cm          No Weed Control   27.10    3.277
0 cm          Weed Wiper      31.87    3.277
10 - 15 cm    Cutlass         51.97    3.277
10 - 15 cm    Hoe             49.60    3.277
10 - 15 cm    Knapsack Sprayer  47.50    3.277
10 - 15 cm    No Weed Control   49.00    3.277
10 - 15 cm    Weed Wiper      54.17    3.277
15 - 20 cm    Cutlass         51.93    3.277
15 - 20 cm    Hoe             51.60    3.277
15 - 20 cm    Knapsack Sprayer  49.90    3.277
15 - 20 cm    No Weed Control   57.17    3.277
15 - 20 cm    Weed Wiper      51.17    3.277
20 - 25 cm    Cutlass         52.47    3.277
20 - 25 cm    Hoe             47.70    3.277
20 - 25 cm    Knapsack Sprayer  51.40    3.277
20 - 25 cm    No Weed Control   54.13    3.277
20 - 25 cm    Weed Wiper      53.93    3.277
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18th July, 2009.

General Linear Model: Girth Stem (mm) versus Block, Ploughing Depth, ...

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Factor           Type   Levels  Values
Block            fixed       3  1, 2, 3
Ploughing Depth  fixed       4  0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control     fixed       5  Cutlass, Hoe, Knapsack Sprayer, No Weed
                                Control, Weed Wiper

Analysis of Variance for Girth Stem (mm), using Adjusted SS for Tests
Source                        DF   Seq SS   Adj SS   Adj MS      F      P
Block                          2  1993.30  1993.30   996.65  32.10  0.000
Ploughing Depth                3  5209.12  5209.12  1736.37  55.92  0.000
Weed Control                   4    99.39    99.39    24.85   0.80  0.533
Ploughing Depth*Weed Control  12   307.30   307.30    25.61   0.82  0.625
Error                         38  1179.97  1179.97    31.05
Total                         59  8789.07

S = 5.57242   R-Sq = 86.57%   R-Sq(adj) = 79.16%

Unusual Observations for Girth Stem (mm)
         Girth
Obs  Stem (mm)      Fit  SE Fit  Residual  St Resid
 44    35.5000  24.8233  3.3743   10.6767      2.41 R

R denotes an observation with a large standardized residual.

Least Squares Means for Girth Stem (mm)
Ploughing De                    Mean  SE Mean
0 cm                           32.07    1.439
10 - 15 cm                     52.05    1.439
15 - 20 cm                     54.21    1.439
20 - 25 cm                     54.21    1.439
Weed Control
Cutlass                        48.41    1.609
Hoe                            47.74    1.609
Knapsack Sprayer               45.88    1.609
No Weed Control                49.01    1.609
Weed Wiper                     49.63    1.609
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Ploughing De*Weed Control			
0 cm	Cutlass	31.30	3.217
0 cm	Hoe	36.67	3.217
0 cm	Knapsack Sprayer	30.17	3.217
0 cm	No Weed Control	29.33	3.217
0 cm	Weed Wiper	32.87	3.217
10 - 15 cm	Cutlass	54.33	3.217
10 - 15 cm	Hoe	51.33	3.217
10 - 15 cm	Knapsack Sprayer	48.93	3.217
10 - 15 cm	No Weed Control	50.73	3.217
10 - 15 cm	Weed Wiper	54.93	3.217
15 - 20 cm	Cutlass	53.33	3.217
15 - 20 cm	Hoe	53.87	3.217
15 - 20 cm	Knapsack Sprayer	51.03	3.217
15 - 20 cm	No Weed Control	59.07	3.217
15 - 20 cm	Weed Wiper	53.73	3.217
20 - 25 cm	Cutlass	54.67	3.217
20 - 25 cm	Hoe	49.10	3.217
20 - 25 cm	Knapsack Sprayer	53.40	3.217
20 - 25 cm	No Weed Control	56.90	3.217
20 - 25 cm	Weed Wiper	56.97	3.217

25th July, 2009.

General Linear Model: Girth Stem (mm) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Girth Stem (mm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	1653.89	1653.89	826.95	25.23	0.000
Ploughing Depth	3	4979.98	4979.98	1659.99	50.65	0.000
Weed Control	4	98.22	98.22	24.56	0.75	0.565
Ploughing Depth*Weed Control	12	276.30	276.30	23.03	0.70	0.739
Error	38	1245.45	1245.45	32.77		
Total	59	8253.85				

S = 5.72494   R-Sq = 84.91%   R-Sq(adj) = 76.57%

Unusual Observations for Girth Stem (mm)

Obs	Girth Stem (mm)	Fit	SE Fit	Residual	St Resid
44	38.3000	26.7767	3.4666	11.5233	2.53 R

R denotes an observation with a large standardized residual.

Least Squares Means for Girth Stem (mm)

Ploughing De		Mean	SE Mean
0 cm		33.59	1.478
10 - 15 cm		53.09	1.478
15 - 20 cm		55.36	1.478
20 - 25 cm		55.13	1.478
Weed Control			
Cutlass		49.56	1.653
Hoe		49.41	1.653
Knapsack Sprayer		46.91	1.653
No Weed Control		49.83	1.653
Weed Wiper		50.75	1.653
Ploughing De*Weed Control			
0 cm	Cutlass	33.10	3.305
0 cm	Hoe	38.73	3.305
0 cm	Knapsack Sprayer	30.67	3.305
0 cm	No Weed Control	31.30	3.305
0 cm	Weed Wiper	34.13	3.305
10 - 15 cm	Cutlass	54.80	3.305

10 - 15 cm	Hoe	52.33	3.305
10 - 15 cm	Knapsack Sprayer	50.57	3.305
10 - 15 cm	No Weed Control	51.70	3.305
10 - 15 cm	Weed Wiper	56.03	3.305
15 - 20 cm	Cutlass	54.47	3.305
15 - 20 cm	Hoe	55.73	3.305
15 - 20 cm	Knapsack Sprayer	52.03	3.305
15 - 20 cm	No Weed Control	59.90	3.305
15 - 20 cm	Weed Wiper	54.67	3.305
20 - 25 cm	Cutlass	55.87	3.305
20 - 25 cm	Hoe	50.83	3.305
20 - 25 cm	Knapsack Sprayer	54.37	3.305
20 - 25 cm	No Weed Control	56.43	3.305
20 - 25 cm	Weed Wiper	58.17	3.305

1st August, 2009.

General Linear Model: Girth Stem (mm) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Girth Stem (mm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	1483.57	1483.57	741.78	21.61	0.000
Ploughing Depth	3	4986.94	4986.94	1662.31	48.43	0.000
Weed Control	4	102.18	102.18	25.55	0.74	0.568
Ploughing Depth*Weed Control	12	312.13	312.13	26.01	0.76	0.688
Error	38	1304.23	1304.23	34.32		
Total	59	8189.04				

S = 5.85848   R-Sq = 84.07%   R-Sq(adj) = 75.27%

Unusual Observations for Girth Stem (mm)

Obs	Girth Stem (mm)	Fit	SE Fit	Residual	St Resid
44	41.0000	29.1700	3.5475	11.8300	2.54 R
45	36.0000	26.0700	3.5475	9.9300	2.13 R

R denotes an observation with a large standardized residual.

Least Squares Means for Girth Stem (mm)

Ploughing De		Mean	SE Mean
0 cm		35.25	1.513
10 - 15 cm		54.71	1.513
15 - 20 cm		57.26	1.513
20 - 25 cm		56.62	1.513
Weed Control			
Cutlass		51.28	1.691
Hoe		51.06	1.691
Knapsack Sprayer		48.62	1.691
No Weed Control		51.19	1.691
Weed Wiper		52.65	1.691
Ploughing De*Weed Control			
0 cm	Cutlass	35.17	3.382
0 cm	Hoe	40.43	3.382
0 cm	Knapsack Sprayer	32.90	3.382
0 cm	No Weed Control	31.77	3.382
0 cm	Weed Wiper	36.00	3.382
10 - 15 cm	Cutlass	56.07	3.382
10 - 15 cm	Hoe	53.63	3.382
10 - 15 cm	Knapsack Sprayer	53.20	3.382
10 - 15 cm	No Weed Control	53.33	3.382
10 - 15 cm	Weed Wiper	57.30	3.382
15 - 20 cm	Cutlass	55.93	3.382
15 - 20 cm	Hoe	58.07	3.382

15 - 20 cm	Knapsack Sprayer	53.50	3.382
15 - 20 cm	No Weed Control	61.90	3.382
15 - 20 cm	Weed Wiper	56.90	3.382
20 - 25 cm	Cutlass	57.97	3.382
20 - 25 cm	Hoe	52.10	3.382
20 - 25 cm	Knapsack Sprayer	54.87	3.382
20 - 25 cm	No Weed Control	57.77	3.382
20 - 25 cm	Weed Wiper	60.40	3.382

8th August, 2009.

General Linear Model: Girth Stem (mm) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Girth Stem (mm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	1372.92	1372.92	686.46	18.61	0.000
Ploughing Depth	3	4637.43	4637.43	1545.81	41.91	0.000
Weed Control	4	72.81	72.81	18.20	0.49	0.740
Ploughing Depth*Weed Control	12	476.74	476.74	39.73	1.08	0.405
Error	38	1401.50	1401.50	36.88		
Total	59	7961.41				

S = 6.07301   R-Sq = 82.40%   R-Sq(adj) = 72.67%

Unusual Observations for Girth Stem (mm)

Obs	Girth Stem (mm)	Fit	SE Fit	Residual	St Resid	
29	72.0000	62.2167	3.6774	9.7833	2.02	R
44	41.3000	30.5950	3.6774	10.7050	2.21	R
45	38.0000	28.2617	3.6774	9.7383	2.01	R

R denotes an observation with a large standardized residual.

Least Squares Means for Girth Stem (mm)

Ploughing De		Mean	SE Mean
0 cm		36.49	1.568
10 - 15 cm		55.51	1.568
15 - 20 cm		57.11	1.568
20 - 25 cm		57.53	1.568
Weed Control			
Cutlass		52.35	1.753
Hoe		52.42	1.753
Knapsack Sprayer		49.50	1.753
No Weed Control		52.24	1.753
Weed Wiper		51.78	1.753
Ploughing De*Weed Control			
0 cm	Cutlass	36.07	3.506
0 cm	Hoe	42.00	3.506
0 cm	Knapsack Sprayer	34.60	3.506
0 cm	No Weed Control	32.83	3.506
0 cm	Weed Wiper	36.93	3.506
10 - 15 cm	Cutlass	57.23	3.506
10 - 15 cm	Hoe	54.80	3.506
10 - 15 cm	Knapsack Sprayer	54.30	3.506
10 - 15 cm	No Weed Control	54.23	3.506
10 - 15 cm	Weed Wiper	57.00	3.506
15 - 20 cm	Cutlass	57.30	3.506
15 - 20 cm	Hoe	59.37	3.506
15 - 20 cm	Knapsack Sprayer	54.87	3.506
15 - 20 cm	No Weed Control	62.73	3.506
15 - 20 cm	Weed Wiper	51.27	3.506
20 - 25 cm	Cutlass	58.80	3.506
20 - 25 cm	Hoe	53.50	3.506

20 - 25 cm	Knapsack Sprayer	54.23	3.506
20 - 25 cm	No Weed Control	59.17	3.506
20 - 25 cm	Weed Wiper	61.93	3.506

NUMBER OF LEAVES

6th June, 2009.

General Linear Model: No of Leaves versus Block, Pl Depth (cm), ...

Factor	Type	Levels	Values
Block	fixed	3	1 2 3
Pl Depth	fixed	4	0 cm 10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con	fixed	5	Cutlass Hoe Knapsack Sprayer No Weed Control Weed Wiper

Analysis of Variance for No of Le, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	0.46052	0.46052	0.23026	5.12	0.011
Pl Depth	3	5.35293	5.35292	1.78431	39.66	0.000
Weed Con	4	0.21127	0.21127	0.05282	1.17	0.338
Pl Depth*Weed Con	12	0.51530	0.51530	0.04294	0.95	0.507
Error	38	1.70968	1.70968	0.04499		
Total	59	8.24970				

Unusual Observations for No of Leaves

Obs	No of Le	Fit	SE Fit	Residual	St Resid
3	3.00000	2.43417	0.12844	0.56583	3.35R
13	2.50000	2.87750	0.12844	-0.37750	-2.24R
23	2.00000	2.46817	0.12844	-0.46817	-2.77R

R denotes an observation with a large standardized residual.

Least Squares Means for No of Leaves

Pl Depth	Mean	SE Mean
0 cm	2.112	0.05477
10 - 15 cm	2.844	0.05477
15 - 20 cm	2.821	0.05477
20 - 25 cm	2.710	0.05477
Weed Con		
Cutlass	2.722	0.06123
Hoe	2.583	0.06123
Knapsack Sprayer	2.555	0.06123
No Weed Control	2.653	0.06123
Weed Wiper	2.597	0.06123

Pl Depth*	Weed Con	Mean	SE Mean
0 cm	Cutlass	2.390	0.12246
0 cm	Hoe	2.057	0.12246
0 cm	Knapsack Sprayer	2.000	0.12246
0 cm	No Weed Control	2.057	0.12246
0 cm	Weed Wiper	2.057	0.12246
10 - 15 cm	Cutlass	2.777	0.12246
10 - 15 cm	Hoe	2.833	0.12246
10 - 15 cm	Knapsack Sprayer	2.667	0.12246
10 - 15 cm	No Weed Control	3.000	0.12246
10 - 15 cm	Weed Wiper	2.943	0.12246
15 - 20 cm	Cutlass	2.833	0.12246
15 - 20 cm	Hoe	2.830	0.12246
15 - 20 cm	Knapsack Sprayer	2.777	0.12246
15 - 20 cm	No Weed Control	2.833	0.12246
15 - 20 cm	Weed Wiper	2.833	0.12246
20 - 25 cm	Cutlass	2.887	0.12246
20 - 25 cm	Hoe	2.610	0.12246
20 - 25 cm	Knapsack Sprayer	2.777	0.12246
20 - 25 cm	No Weed Control	2.723	0.12246
20 - 25 cm	Weed Wiper	2.553	0.12246

13th June, 2009.

General Linear Model: No of Leaves versus Block, Pl Depth (cm), ...

```
Factor     Type Levels Values
Block     fixed      3 1 2 3
Pl Depth  fixed      4 0 cm       10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con  fixed      5 Cutlass          Hoe               Knapsack Sprayer
                       No Weed Control  Weed Wiper

Analysis of Variance for No of Le, using Adjusted SS for Tests
Source              DF     Seq SS     Adj SS     Adj MS       F      P
Block                2    3.55952    3.55952    1.77976   20.80  0.000
Pl Depth             3    5.11874    5.11874    1.70625   19.94  0.000
Weed Con             4    0.10049    0.10049    0.02512    0.29  0.880
Pl Depth*Weed Con   12    1.21532    1.21532    0.10128    1.18  0.329
Error               38    3.25214    3.25214    0.08558
Total               59   13.24622

Unusual Observations for No of Le
Obs  No of Le       Fit      SE Fit  Residual   St Resid
  5   5.00000   4.51350     0.17714   0.48650      2.09R
 25   4.00000   4.49750     0.17714  -0.49750     -2.14R

R denotes an observation with a large standardized residual.

Least Squares Means for No of Le
  Pl Depth                       Mean   SE Mean
0 cm                            4.557   0.07553
10 - 15 cm                      5.156   0.07553
15 - 20 cm                      5.309   0.07553
20 - 25 cm                      5.189   0.07553
        Weed Con
Cutlass                         5.084   0.08445
Hoe                             5.098   0.08445
Knapsack Sprayer                4.986   0.08445
No Weed Control                 5.069   0.08445
Weed Wiper                      5.027   0.08445

  Pl Depth*       Weed Con
0 cm       Cutlass              4.670   0.16890
0 cm       Hoe                  4.890   0.16890
0 cm       Knapsack Sprayer     4.333   0.16890
0 cm       No Weed Control      4.277   0.16890
0 cm       Weed Wiper           4.613   0.16890
10 - 15 cm Cutlass              5.223   0.16890
10 - 15 cm Hoe                  5.000   0.16890
10 - 15 cm Knapsack Sprayer     5.110   0.16890
10 - 15 cm No Weed Control      5.280   0.16890
10 - 15 cm Weed Wiper           5.167   0.16890
15 - 20 cm Cutlass              5.220   0.16890
15 - 20 cm Hoe                  5.443   0.16890
15 - 20 cm Knapsack Sprayer     5.220   0.16890
15 - 20 cm No Weed Control      5.333   0.16890
15 - 20 cm Weed Wiper           5.330   0.16890
20 - 25 cm Cutlass              5.223   0.16890
20 - 25 cm Hoe                  5.057   0.16890
20 - 25 cm Knapsack Sprayer     5.280   0.16890
20 - 25 cm No Weed Control      5.387   0.16890
20 - 25 cm Weed Wiper           5.000   0.16890
```

20th June, 2009.

General Linear Model: No of Leaves versus Block, Pl Depth (cm), ...

```
Factor     Type Levels Values
Block     fixed      3 1 2 3
Pl Depth  fixed      4 0 cm       10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con  fixed      5 Cutlass          Hoe               Knapsack Sprayer
                       No Weed Control  Weed Wiper

Analysis of Variance for No of Le, using Adjusted SS for Tests
```

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	8.0343	8.0343	4.0172	44.06	0.000
Pl Depth	3	10.4720	10.4720	3.4907	38.28	0.000
Weed Con	4	0.6399	0.6399	0.1600	1.75	0.158
Pl Depth*Weed Con	12	2.0209	2.0209	0.1684	1.85	0.075
Error	38	3.4648	3.4648	0.0912		
Total	59	24.6319				

Unusual Observations for No of Le

Obs	No of Le	Fit	SE Fit	Residual	St Resid
25	6.00000	6.50950	0.18284	-0.50950	-2.12R
31	8.50000	8.01283	0.18284	0.48717	2.03R
39	7.00000	7.56617	0.18284	-0.56617	-2.36R

R denotes an observation with a large standardized residual.

Least Squares Means for No of Le

Pl Depth	Mean	SE Mean
0 cm	6.565	0.07797
10 - 15 cm	7.579	0.07797
15 - 20 cm	7.577	0.07797
20 - 25 cm	7.379	0.07797
Weed Con		
Cutlass	7.347	0.08717
Hoe	7.417	0.08717
Knapsack Sprayer	7.111	0.08717
No Weed Control	7.252	0.08717
Weed Wiper	7.250	0.08717

Pl Depth*	Weed Con	Mean	SE Mean
0 cm	Cutlass	6.663	0.17434
0 cm	Hoe	7.110	0.17434
0 cm	Knapsack Sprayer	6.277	0.17434
0 cm	No Weed Control	6.057	0.17434
0 cm	Weed Wiper	6.720	0.17434
10 - 15 cm	Cutlass	7.667	0.17434
10 - 15 cm	Hoe	7.557	0.17434
10 - 15 cm	Knapsack Sprayer	7.447	0.17434
10 - 15 cm	No Weed Control	7.723	0.17434
10 - 15 cm	Weed Wiper	7.500	0.17434
15 - 20 cm	Cutlass	7.610	0.17434
15 - 20 cm	Hoe	7.720	0.17434
15 - 20 cm	Knapsack Sprayer	7.330	0.17434
15 - 20 cm	No Weed Control	7.780	0.17434
15 - 20 cm	Weed Wiper	7.447	0.17434
20 - 25 cm	Cutlass	7.447	0.17434
20 - 25 cm	Hoe	7.280	0.17434
20 - 25 cm	Knapsack Sprayer	7.390	0.17434
20 - 25 cm	No Weed Control	7.447	0.17434
20 - 25 cm	Weed Wiper	7.333	0.17434

27th June, 2009.

General Linear Model: No of Leaves versus Block, Pl Depth (cm), ...

Factor	Type	Levels	Values
Block	fixed	3	1 2 3
Pl Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Con	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for No of Le, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	15.5770	15.5770	7.7885	40.10	0.000
Pl Depth	3	25.2086	25.2086	8.4029	43.26	0.000
Weed Con	4	0.3821	0.3821	0.0955	0.49	0.742
Pl Depth*Weed Con	12	2.3609	2.3609	0.1967	1.01	0.457
Error	38	7.3813	7.3813	0.1942		
Total	59	50.9100				

```
Unusual Observations for No of Le
Obs  No of Le       Fit      SE Fit  Residual   St Resid
 25    7.1700    8.1018      0.2669   -0.9318     -2.66R

R denotes an observation with a large standardized residual.

Least Squares Means for No of Le
  Pl Depth                            Mean   SE Mean
0 cm                                 7.655    0.1138
10 - 15 cm                           9.035    0.1138
15 - 20 cm                           9.367    0.1138
20 - 25 cm                           8.889    0.1138
        Weed Con
Cutlass                              8.736    0.1272
Hoe                                  8.723    0.1272
Knapsack Sprayer                     8.612    0.1272
No Weed Control                      8.750    0.1272
Weed Wiper                           8.862    0.1272

  Pl Depth*        Weed Con
0 cm       Cutlass                   7.387    0.2545
0 cm       Hoe                       8.110    0.2545
0 cm       Knapsack Sprayer          7.613    0.2545
0 cm       No Weed Control           7.387    0.2545
0 cm       Weed Wiper                7.777    0.2545
10 - 15 cm Cutlass                   9.333    0.2545
10 - 15 cm Hoe                       8.667    0.2545
10 - 15 cm Knapsack Sprayer          8.780    0.2545
10 - 15 cm No Weed Control           9.223    0.2545
10 - 15 cm Weed Wiper                9.170    0.2545
15 - 20 cm Cutlass                   9.223    0.2545
15 - 20 cm Hoe                       9.447    0.2545
15 - 20 cm Knapsack Sprayer          9.220    0.2545
15 - 20 cm No Weed Control           9.557    0.2545
15 - 20 cm Weed Wiper                9.390    0.2545
20 - 25 cm Cutlass                   9.000    0.2545
20 - 25 cm Hoe                       8.667    0.2545
20 - 25 cm Knapsack Sprayer          8.833    0.2545
20 - 25 cm No Weed Control           8.833    0.2545
20 - 25 cm Weed Wiper                9.113    0.2545
```

4th July, 2009.

General Linear Model: No of Leaves versus Block, Pl Depth (cm), ...

```
Factor     Type Levels Values
Block     fixed      3 1 2 3
Pl Depth  fixed      4 0 cm       10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con  fixed      5 Cutlass         Hoe              Knapsack Sprayer
                       No Weed Control  Weed Wiper

Analysis of Variance for No of Le, using Adjusted SS for Tests
Source              DF     Seq SS     Adj SS     Adj MS       F      P
Block                2    38.0355    38.0355    19.0178   42.77  0.000
Pl Depth             3    52.7156    52.7156    17.5719   39.52  0.000
Weed Con             4     1.0550     1.0550     0.2638    0.59  0.670
Pl Depth*Weed Con   12     3.4094     3.4094     0.2841    0.64  0.796
Error               38    16.8962    16.8962     0.4446
Total               59   112.1117

Unusual Observations for No of Le
Obs  No of Le       Fit      SE Fit  Residual   St Resid
 41    8.1700    7.0982      0.4038    1.0718      2.02R
 44    9.0000    7.8215      0.4038    1.1785      2.22R

R denotes an observation with a large standardized residual.
```

Least Squares Means for No of Le

Pl Depth	Mean	SE Mean
0 cm	8.667	0.1722
10 - 15 cm	10.810	0.1722
15 - 20 cm	10.956	0.1722
20 - 25 cm	10.699	0.1722
Weed Con		
Cutlass	10.318	0.1925
Hoe	10.362	0.1925
Knapsack Sprayer	10.027	0.1925
No Weed Control	10.307	0.1925
Weed Wiper	10.402	0.1925

Pl Depth*	Weed Con		
0 cm	Cutlass	8.777	0.3850
0 cm	Hoe	9.223	0.3850
0 cm	Knapsack Sprayer	8.167	0.3850
0 cm	No Weed Control	8.223	0.3850
0 cm	Weed Wiper	8.947	0.3850
10 - 15 cm	Cutlass	10.887	0.3850
10 - 15 cm	Hoe	10.610	0.3850
10 - 15 cm	Knapsack Sprayer	10.497	0.3850
10 - 15 cm	No Weed Control	10.837	0.3850
10 - 15 cm	Weed Wiper	11.220	0.3850
15 - 20 cm	Cutlass	10.833	0.3850
15 - 20 cm	Hoe	11.170	0.3850
15 - 20 cm	Knapsack Sprayer	10.777	0.3850
15 - 20 cm	No Weed Control	11.223	0.3850
15 - 20 cm	Weed Wiper	10.777	0.3850
20 - 25 cm	Cutlass	10.777	0.3850
20 - 25 cm	Hoe	10.447	0.3850
20 - 25 cm	Knapsack Sprayer	10.667	0.3850
20 - 25 cm	No Weed Control	10.943	0.3850
20 - 25 cm	Weed Wiper	10.663	0.3850

11th July, 2009.

General Linear Model: No of Leaves versus Block, Pl Depth (cm), ...

Factor	Type	Levels	Values
Block	fixed	3	1 2 3
Pl Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Con	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for No of Le, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	47.0975	47.0975	23.5487	34.77	0.000
Pl Depth	3	97.2565	97.2565	32.4188	47.86	0.000
Weed Con	4	1.5384	1.5384	0.3846	0.57	0.688
Pl Depth*Weed Con	12	9.8836	9.8836	0.8236	1.22	0.308
Error	38	25.7391	25.7391	0.6773		
Total	59	181.5151				

Unusual Observations for No of Le

Obs	No of Le	Fit	SE Fit	Residual	St Resid
25	8.6700	10.0078	0.4984	-1.3378	-2.04R
44	10.6700	8.9762	0.4984	1.6938	2.59R

R denotes an observation with a large standardized residual.

Least Squares Means for No of Le

Pl Depth	Mean	SE Mean
0 cm	9.811	0.2125
10 - 15 cm	12.745	0.2125
15 - 20 cm	12.833	0.2125
20 - 25 cm	12.667	0.2125
Weed Con		
Cutlass	12.098	0.2376

Hoe	12.180	0.2376
Knapsack Sprayer	11.765	0.2376
No Weed Control	11.888	0.2376
Weed Wiper	12.140	0.2376

Pl Depth*	Weed Con		
0 cm	Cutlass	9.833	0.4752
0 cm	Hoe	10.830	0.4752
0 cm	Knapsack Sprayer	9.280	0.4752
0 cm	No Weed Control	8.890	0.4752
0 cm	Weed Wiper	10.223	0.4752
10 - 15 cm	Cutlass	12.943	0.4752
10 - 15 cm	Hoe	12.500	0.4752
10 - 15 cm	Knapsack Sprayer	12.390	0.4752
10 - 15 cm	No Weed Control	12.610	0.4752
10 - 15 cm	Weed Wiper	13.280	0.4752
15 - 20 cm	Cutlass	12.723	0.4752
15 - 20 cm	Hoe	13.167	0.4752
15 - 20 cm	Knapsack Sprayer	12.610	0.4752
15 - 20 cm	No Weed Control	13.333	0.4752
15 - 20 cm	Weed Wiper	12.333	0.4752
20 - 25 cm	Cutlass	12.890	0.4752
20 - 25 cm	Hoe	12.223	0.4752
20 - 25 cm	Knapsack Sprayer	12.780	0.4752
20 - 25 cm	No Weed Control	12.720	0.4752
20 - 25 cm	Weed Wiper	12.723	0.4752

18th July, 2009.

General Linear Model: No of Leaves versus Block, Pl Depth (cm), ...

Factor	Type	Levels	Values
Block	fixed	3	1 2 3
Pl Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Con	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for No of Le, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	54.1879	54.1879	27.0939	31.78	0.000
Pl Depth	3	108.4673	108.4673	36.1558	42.41	0.000
Weed Con	4	1.8847	1.8847	0.4712	0.55	0.698
Pl Depth*Weed Con	12	11.9816	11.9816	0.9985	1.17	0.337
Error	38	32.3995	32.3995	0.8526		
Total	59	208.9209				

Unusual Observations for No of Le

Obs	No of Le	Fit	SE Fit	Residual	St Resid
25	9.3300	10.8785	0.5591	-1.5485	-2.11R
44	11.8300	9.8762	0.5591	1.9538	2.66R

R denotes an observation with a large standardized residual.

Least Squares Means for No of Le

Pl Depth	Mean	SE Mean
0 cm	10.877	0.2384
10 - 15 cm	13.945	0.2384
15 - 20 cm	14.099	0.2384
20 - 25 cm	13.889	0.2384
Weed Con		
Cutlass	13.347	0.2666
Hoe	13.375	0.2666
Knapsack Sprayer	12.888	0.2666
No Weed Control	13.138	0.2666
Weed Wiper	13.263	0.2666

Pl Depth*	Weed Con		
0 cm	Cutlass	11.053	0.5331
0 cm	Hoe	11.947	0.5331

0 cm	Knapsack Sprayer	10.223	0.5331
0 cm	No Weed Control	9.943	0.5331
0 cm	Weed Wiper	11.220	0.5331
10 - 15 cm	Cutlass	14.167	0.5331
10 - 15 cm	Hoe	13.837	0.5331
10 - 15 cm	Knapsack Sprayer	13.610	0.5331
10 - 15 cm	No Weed Control	13.720	0.5331
10 - 15 cm	Weed Wiper	14.390	0.5331
15 - 20 cm	Cutlass	13.943	0.5331
15 - 20 cm	Hoe	14.387	0.5331
15 - 20 cm	Knapsack Sprayer	13.997	0.5331
15 - 20 cm	No Weed Control	14.777	0.5331
15 - 20 cm	Weed Wiper	13.390	0.5331
20 - 25 cm	Cutlass	14.223	0.5331
20 - 25 cm	Hoe	13.330	0.5331
20 - 25 cm	Knapsack Sprayer	13.723	0.5331
20 - 25 cm	No Weed Control	14.113	0.5331
20 - 25 cm	Weed Wiper	14.053	0.5331

25th July, 2009.

General Linear Model: No of Leaves versus Block, Pl Depth (cm), ...

Factor	Type	Levels	Values
Block	fixed	3	1 2 3
Pl Depth	fixed	4	0 cm 10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con	fixed	5	Cutlass Hoe Knapsack Sprayer No Weed Control Weed Wiper

Analysis of Variance for No of Le, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	73.850	73.850	36.925	40.92	0.000
Pl Depth	3	115.090	115.090	38.363	42.51	0.000
Weed Con	4	6.084	6.084	1.521	1.69	0.173
Pl Depth*Weed Con	12	16.937	16.937	1.411	1.56	0.144
Error	38	34.290	34.290	0.902		
Total	59	246.251				

Unusual Observations for No of Le

Obs	No of Le	Fit	SE Fit	Residual	St Resid
4	11.6700	13.7908	0.5752	-2.1208	-2.81R
25	10.3300	12.0263	0.5752	-1.6963	-2.24R
44	13.3300	11.2328	0.5752	2.0972	2.77R

R denotes an observation with a large standardized residual.

Least Squares Means for No of Le

Pl Depth	Mean	SE Mean
0 cm	12.59	0.2453
10 - 15 cm	15.93	0.2453
15 - 20 cm	15.81	0.2453
20 - 25 cm	15.58	0.2453
Weed Con		
Cutlass	15.29	0.2742
Hoe	15.28	0.2742
Knapsack Sprayer	14.42	0.2742
No Weed Control	14.97	0.2742
Weed Wiper	14.93	0.2742

Pl Depth*	Weed Con		
0 cm	Cutlass	13.17	0.5484
0 cm	Hoe	13.95	0.5484
0 cm	Knapsack Sprayer	11.50	0.5484
0 cm	No Weed Control	11.56	0.5484
0 cm	Weed Wiper	12.78	0.5484
10 - 15 cm	Cutlass	16.17	0.5484
10 - 15 cm	Hoe	15.67	0.5484
10 - 15 cm	Knapsack Sprayer	15.39	0.5484
10 - 15 cm	No Weed Control	16.05	0.5484

```
10 - 15 cm Weed Wiper          16.39    0.5484
15 - 20 cm Cutlass             16.00    0.5484
15 - 20 cm Hoe                 16.28    0.5484
15 - 20 cm Knapsack Sprayer    15.72    0.5484
15 - 20 cm No Weed Control     16.39    0.5484
15 - 20 cm Weed Wiper          14.67    0.5484
20 - 25 cm Cutlass             15.83    0.5484
20 - 25 cm Hoe                 15.22    0.5484
20 - 25 cm Knapsack Sprayer    15.06    0.5484
20 - 25 cm No Weed Control     15.89    0.5484
20 - 25 cm Weed Wiper          15.89    0.5484
```

1st August, 2009.

General Linear Model: No of Leaves versus Block, Pl Depth (cm), ...

```
Factor     Type Levels Values
Block     fixed      3 1 2 3
Pl Depth  fixed      4 0 cm       10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con  fixed      5 Cutlass          Hoe              Knapsack Sprayer
                       No Weed Control  Weed Wiper

Analysis of Variance for No of Le, using Adjusted SS for Tests
Source              DF     Seq SS     Adj SS     Adj MS       F       P
Block                2    20.4054    20.4054    10.2027   13.94   0.000
Pl Depth             3    82.9935    82.9935    27.6645   37.80   0.000
Weed Con             4     9.5803     9.5803     2.3951    3.27   0.021
Pl Depth*Weed Con   12    14.9758    14.9758     1.2480    1.71   0.104
Error               38    27.8126    27.8126     0.7319
Total               59   155.7677

Unusual Observations for No of Le
Obs  No of Le       Fit      SE Fit  Residual   St Resid
  4   13.5000   15.3042      0.5180   -1.8042     -2.65R
  5   15.3300   13.9175      0.5180    1.4125      2.07R
 41   14.5000   13.0640      0.5180    1.4360      2.11R
 44   15.8300   14.1207      0.5180    1.7093      2.51R
 55   14.6700   16.0673      0.5180   -1.3973     -2.05R

R denotes an observation with a large standardized residual.

Least Squares Means for No of Le
  Pl Depth                        Mean   SE Mean
0 cm                             14.87    0.2209
10 - 15 cm                       17.71    0.2209
15 - 20 cm                       17.56    0.2209
20 - 25 cm                       17.46    0.2209
        Weed Con
Cutlass                          17.19    0.2470
Hoe                              17.33    0.2470
Knapsack Sprayer                 16.20    0.2470
No Weed Control                  16.77    0.2470
Weed Wiper                       17.00    0.2470

  Pl Depth*        Weed Con
0 cm       Cutlass               15.22    0.4939
0 cm       Hoe                   16.72    0.4939
0 cm       Knapsack Sprayer      13.56    0.4939
0 cm       No Weed Control       13.89    0.4939
0 cm       Weed Wiper            14.94    0.4939
10 - 15 cm Cutlass               17.89    0.4939
10 - 15 cm Hoe                   17.61    0.4939
10 - 15 cm Knapsack Sprayer      17.28    0.4939
10 - 15 cm No Weed Control       17.61    0.4939
10 - 15 cm Weed Wiper            18.17    0.4939
15 - 20 cm Cutlass               18.05    0.4939
15 - 20 cm Hoe                   17.50    0.4939
15 - 20 cm Knapsack Sprayer      16.89    0.4939
15 - 20 cm No Weed Control       18.17    0.4939
```

15 - 20 cm Weed Wiper	17.17	0.4939
20 - 25 cm Cutlass	17.61	0.4939
20 - 25 cm Hoe	17.50	0.4939
20 - 25 cm Knapsack Sprayer	17.06	0.4939
20 - 25 cm No Weed Control	17.39	0.4939
20 - 25 cm Weed Wiper	17.72	0.4939

8th August, 2009.

General Linear Model: No of Leaves versus Block, Pl Depth (cm), ...

```
Factor     Type Levels Values
Block     fixed      3 1 2 3
Pl Depth  fixed      4 0 cm       10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con  fixed      5 Cutlass          Hoe              Knapsack Sprayer
                       No Weed Control  Weed Wiper
```

Analysis of Variance for No of Le, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	20.6472	20.6472	10.3236	14.06	0.000
Pl Depth	3	83.3679	83.3679	27.7893	37.85	0.000
Weed Con	4	9.7833	9.7833	2.4458	3.33	0.020
Pl Depth*Weed Con	12	14.9053	14.9053	1.2421	1.69	0.108
Error	38	27.8987	27.8987	0.7342		
Total	59	156.6023				

Unusual Observations for No of Le

Obs	No of Le	Fit	SE Fit	Residual	St Resid
4	13.5000	15.3152	0.5188	-1.8152	-2.66R
5	15.3300	13.9285	0.5188	1.4015	2.06R
41	14.5000	13.0585	0.5188	1.4415	2.11R
44	15.8300	14.1152	0.5188	1.7148	2.51R
55	14.6700	16.0618	0.5188	-1.3918	-2.04R

R denotes an observation with a large standardized residual.

Least Squares Means for No of Le

Pl Depth	Mean	SE Mean
0 cm	14.87	0.2212
10 - 15 cm	17.71	0.2212
15 - 20 cm	17.56	0.2212
20 - 25 cm	17.48	0.2212
Weed Con		
Cutlass	17.22	0.2473
Hoe	17.33	0.2473
Knapsack Sprayer	16.20	0.2473
No Weed Control	16.77	0.2473
Weed Wiper	17.00	0.2473
Pl Depth* Weed Con		
0 cm Cutlass	15.22	0.4947
0 cm Hoe	16.72	0.4947
0 cm Knapsack Sprayer	13.56	0.4947
0 cm No Weed Control	13.89	0.4947
0 cm Weed Wiper	14.94	0.4947
10 - 15 cm Cutlass	17.89	0.4947
10 - 15 cm Hoe	17.61	0.4947
10 - 15 cm Knapsack Sprayer	17.28	0.4947
10 - 15 cm No Weed Control	17.61	0.4947
10 - 15 cm Weed Wiper	18.17	0.4947
15 - 20 cm Cutlass	18.05	0.4947
15 - 20 cm Hoe	17.50	0.4947
15 - 20 cm Knapsack Sprayer	16.89	0.4947
15 - 20 cm No Weed Control	18.17	0.4947
15 - 20 cm Weed Wiper	17.17	0.4947
20 - 25 cm Cutlass	17.72	0.4947
20 - 25 cm Hoe	17.50	0.4947
20 - 25 cm Knapsack Sprayer	17.06	0.4947
20 - 25 cm No Weed Control	17.39	0.4947

20 - 25 cm Weed Wiper	17.72	0.4947

OBAATANPA MAIZE ROOT LENGTH (cm) ANOVA

5th September, 2009.

General Linear Model: Root length (cm) versus Block, Pl Depth (cm), ...

Factor	Type	Levels	Values
Block	fixed	3	1 2 3
Pl Depth	fixed	4	0 cm 10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con	fixed	5	Cutlass Hoe Knapsack Sprayer No Weed Control Weed Wiper

Analysis of Variance for Root length, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	454.91	454.91	227.45	15.22	0.000
Pl Depth	3	3539.25	3539.25	1179.75	78.95	0.000
Weed Control	4	43.06	43.06	10.76	0.72	0.583
Pl Depth*Weed Con	12	117.29	117.29	9.77	0.65	0.782
Error	38	567.80	567.80	14.94		
Total	59	4722.32				

Unusual Observations for Root length

Obs	Root len	Fit	SE Fit	Residual	St Resid
9	51.6700	43.4850	2.3407	8.1850	2.66R
29	42.6700	49.7860	2.3407	-7.1160	-2.31R
36	55.3000	48.8827	2.3407	6.4173	2.09R

R denotes an observation with a large standardized residual.

Least Squares Means for Root length

Pl Depth	Mean	SE Mean
0 cm	27.72	0.9981
10 - 15 cm	45.85	0.9981
15 - 20 cm	43.74	0.9981
20 - 25 cm	46.34	0.9981

Weed Control		
Cutlass	41.24	1.1159
Hoe	41.62	1.1159
Knapsack Sprayer	39.62	1.1159
No Weed Control	40.26	1.1159
Weed Wiper	41.85	1.1159

Pl Depth*	Weed Con		
0 cm	Cutlass	29.74	2.2318
0 cm	Hoe	29.64	2.2318
0 cm	Knapsack Sprayer	26.92	2.2318
0 cm	No Weed Control	25.64	2.2318
0 cm	Weed Wiper	26.65	2.2318
10 - 15 cm	Cutlass	47.62	2.2318
10 - 15 cm	Hoe	47.04	2.2318
10 - 15 cm	Knapsack Sprayer	41.19	2.2318
10 - 15 cm	No Weed Control	46.08	2.2318
10 - 15 cm	Weed Wiper	47.33	2.2318
15 - 20 cm	Cutlass	43.10	2.2318
15 - 20 cm	Hoe	43.97	2.2318
15 - 20 cm	Knapsack Sprayer	43.35	2.2318
15 - 20 cm	No Weed Control	42.87	2.2318
15 - 20 cm	Weed Wiper	45.42	2.2318
20 - 25 cm	Cutlass	44.49	2.2318
20 - 25 cm	Hoe	45.81	2.2318
20 - 25 cm	Knapsack Sprayer	47.00	2.2318
20 - 25 cm	No Weed Control	46.43	2.2318
20 - 25 cm	Weed Wiper	47.99	2.2318

OBAATANPA MAIZE DRY MATTER YIELD

5TH SEPTEMBER, 2009

General Linear Model: Dry Matter Yield versus Block, Pl Depth (cm), ...

```
Factor          Type   Levels  Values
Block           fixed       3  1, 2, 3
Pl Depth (cm)   fixed       4  0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control    fixed       5  Cutlass, Hoe, Knapsack Sprayer, No Weed Control,
                               Weed Wiper

Analysis of Variance for Dry Matter Yield (kg/Ha), using Adjusted SS for Tests
Source                       DF     Seq SS     Adj SS     Adj MS      F      P
Block                         2  254582903  254582903  127291452  27.62  0.000
Pl Depth (cm)                 3  250404016  250404016   83468005  18.11  0.000
Weed Control                  4   33202014   33202014    8300504   1.80  0.149
Pl Depth (cm)*Weed Control   12   26620075   26620075    2218340   0.48  0.913
Error                        38  175148931  175148931    4609182
Total                        59  739957940

S = 2146.90   R-Sq = 76.33%   R-Sq(adj) = 63.25%
Unusual Observations for Dry Matter Yield (kg/Ha)
     Dry Matter           Yield
Obs     (kg/Ha)       Fit  SE Fit  Residual  St Resid
 18     13306.3    9760.4  1300.0    3545.9      2.08 R
 20     16916.7   12425.9  1300.0    4490.8      2.63 R
 60      3915.8    7394.7  1300.0   -3478.9     -2.04 R

R denotes an observation with a large standardized residual.

Least Squares Means for Dry Matter Yield (kg/Ha)
Pl Depth (cm                    Mean  SE Mean
0 cm                            2573    554.3
10 - 15 cm                      5743    554.3
15 - 20 cm                      6654    554.3
20 - 25 cm                      8155    554.3

Weed Control
Cutlass                         5790    619.8
Hoe                             6107    619.8
Knapsack Sprayer                6315    619.8
No Weed Control                 4348    619.8
Weed Wiper                      6348    619.8

Pl Depth (cm*Weed Control
0 cm          Cutlass           3114   1239.5
0 cm          Hoe               2944   1239.5
0 cm          Knapsack Sprayer  2467   1239.5
0 cm          No Weed Control   1541   1239.5
0 cm          Weed Wiper        2799   1239.5
10 - 15 cm    Cutlass           5984   1239.5
10 - 15 cm    Hoe               6638   1239.5
10 - 15 cm    Knapsack Sprayer  4836   1239.5
10 - 15 cm    No Weed Control   3915   1239.5
10 - 15 cm    Weed Wiper        7341   1239.5
15 - 20 cm    Cutlass           6707   1239.5
15 - 20 cm    Hoe               6597   1239.5
15 - 20 cm    Knapsack Sprayer  8067   1239.5
15 - 20 cm    No Weed Control   5501   1239.5
15 - 20 cm    Weed Wiper        6399   1239.5
20 - 25 cm    Cutlass           7355   1239.5
20 - 25 cm    Hoe               8249   1239.5
20 - 25 cm    Knapsack Sprayer 10020   1239.5
20 - 25 cm    No Weed Control   6433   1239.5
20 - 25 cm    Weed Wiper        8720   1239.5
```

PENETRATION RESISTANCE

MINITAB STATISTICAL SOFTWARE ANOVA OUTPUT

20TH MAY, 2009.

General Linear Model: Pen Res (kPa) versus Block, Pl Depth (cm), ...

```
Factor     Type Levels Values
Block      fixed      3 1 2 3
Pl Depth   fixed      4 0 cm       10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con   fixed      5 Cutlass          Hoe              Knapsack Sprayer
                        No Weed Control  Weed Wiper

Analysis of Variance for Pen Res, using Adjusted SS for Tests
Source                DF     Seq SS     Adj SS     Adj MS       F      P
Block                  2      32816      32816      16408   12.40  0.000
Pl Depth               3       4669       4669       1556    1.18  0.332
Weed Con               4       1950       1950        488    0.37  0.830
Pl Depth*Weed Con     12       8180       8180        682    0.52  0.892
Error                 38      50276      50276       1323
Total                 59      97892

Unusual Observations for Pen Res
Obs    Pen Res       Fit      SE Fit  Residual   St Resid
  8    510.120   578.117      22.025   -67.997     -2.35R
 41    695.280   620.011      22.025    75.269      2.60R

R denotes an observation with a large standardized residual.

Least Squares Means for Pen Res
  Pl Depth                         Mean   SE Mean
0 cm                              579.3     9.392
10 - 15 cm                        568.9     9.392
15 - 20 cm                        560.6     9.392
20 - 25 cm                        556.1     9.392

        Weed Con
Cutlass                           567.8    10.500
Hoe                               568.1    10.500
Knapsack Sprayer                  569.0    10.500
No Weed Control                   555.1    10.500
Weed Wiper                        571.2    10.500

  Pl Depth*        Weed Con
0 cm       Cutlass                571.4    21.000
0 cm       Hoe                    578.0    21.000
0 cm       Knapsack Sprayer       575.5    21.000
0 cm       No Weed Control        587.0    21.000
0 cm       Weed Wiper             584.5    21.000
10 - 15 cm Cutlass                593.5    21.000
10 - 15 cm Hoe                    578.8    21.000
10 - 15 cm Knapsack Sprayer       578.0    21.000
10 - 15 cm No Weed Control        545.7    21.000
10 - 15 cm Weed Wiper             548.5    21.000
15 - 20 cm Cutlass                549.0    21.000
15 - 20 cm Hoe                    565.7    21.000
15 - 20 cm Knapsack Sprayer       564.9    21.000
15 - 20 cm No Weed Control        538.3    21.000
15 - 20 cm Weed Wiper             584.9    21.000
20 - 25 cm Cutlass                557.1    21.000
20 - 25 cm Hoe                    549.8    21.000
20 - 25 cm Knapsack Sprayer       557.5    21.000
20 - 25 cm No Weed Control        549.4    21.000
20 - 25 cm Weed Wiper             566.9    21.000
```

General Linear Model: Pen Res (kPa) versus Block, Pl Depth (cm), ...

```
Factor     Type Levels Values
Block      fixed      3 1 2 3
Pl Depth   fixed      4 0 cm       10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con   fixed      5 Cutlass          Hoe              Knapsack Sprayer
                        No Weed Control  Weed Wiper

Analysis of Variance for Pen Res, using Adjusted SS for Tests
Source                DF     Seq SS     Adj SS     Adj MS       F      P
Block                  2      32816      32816      16408   12.40  0.000
```

Pl Depth	3	4669	4669	1556	1.18	0.332
Weed Con	4	1950	1950	488	0.37	0.830
Pl Depth*Weed Con	12	8180	8180	682	0.52	0.892
Error	38	50276	50276	1323		
Total	59	97892				

Unusual Observations for Pen Res

Obs	Pen Res	Fit	SE Fit	Residual	St Resid
8	510.120	578.117	22.025	-67.997	-2.35R
41	695.280	620.011	22.025	75.269	2.60R

R denotes an observation with a large standardized residual.

Least Squares Means for Pen Res

Pl Depth	Mean	SE Mean
0 cm	579.3	9.392
10 - 15 cm	568.9	9.392
15 - 20 cm	560.6	9.392
20 - 25 cm	556.1	9.392
Weed Con		
Cutlass	567.8	10.500
Hoe	568.1	10.500
Knapsack Sprayer	569.0	10.500
No Weed Control	555.1	10.500
Weed Wiper	571.2	10.500

5TH AUGUST, 2009.

General Linear Model: Pen Res (kPa) versus Block, Pl Depth (cm), ...

Factor	Type	Levels	Values
Block	fixed	3	1 2 3
Pl Depth	fixed	4	0 cm 10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con	fixed	5	Cutlass Hoe Knapsack Sprayer No Weed Control Weed Wiper

Analysis of Variance for Pen Res, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	2586	2586	1293	1.20	0.313
Pl Depth	3	9114	9114	3038	2.82	0.052
Weed Con	4	4745	4745	1186	1.10	0.371
Pl Depth*Weed Con	12	11679	11679	973	0.90	0.553
Error	38	40984	40984	1079		
Total	59	69108				

Unusual Observations for Pen Res

Obs	Pen Res	Fit	SE Fit	Residual	St Resid
24	499.080	415.073	19.886	84.007	3.21R

R denotes an observation with a large standardized residual.

Least Squares Means for Pen Res

Pl Depth		Mean	SE Mean
0 cm		424.9	8.479
10 - 15 cm		404.1	8.479
15 - 20 cm		390.5	8.479
20 - 25 cm		403.9	8.479
Weed Con			
Cutlass		412.1	9.480
Hoe		416.9	9.480
Knapsack Sprayer		397.2	9.480
No Weed Control		409.3	9.480
Weed Wiper		393.7	9.480
Pl Depth*	Weed Con		
0 cm	Cutlass	423.1	18.961
0 cm	Hoe	434.5	18.961
0 cm	Knapsack Sprayer	422.5	18.961

```
0 cm       No Weed Control      429.7    18.961
0 cm       Weed Wiper           414.9    18.961
10 - 15 cm Cutlass              401.4    18.961
10 - 15 cm Hoe                  420.2    18.961
10 - 15 cm Knapsack Sprayer     418.2    18.961
10 - 15 cm No Weed Control      393.8    18.961
10 - 15 cm Weed Wiper           387.1    18.961
15 - 20 cm Cutlass              431.2    18.961
15 - 20 cm Hoe                  378.1    18.961
15 - 20 cm Knapsack Sprayer     367.1    18.961
15 - 20 cm No Weed Control      398.3    18.961
15 - 20 cm Weed Wiper           377.7    18.961
20 - 25 cm Cutlass              392.9    18.961
20 - 25 cm Hoe                  434.7    18.961
20 - 25 cm Knapsack Sprayer     381.0    18.961
20 - 25 cm No Weed Control      415.5    18.961
20 - 25 cm Weed Wiper           395.3    18.961
```

5TH OCTOBER, 2009.

General Linear Model: Pen Res (kPa) versus Block, Pl Depth (cm), ...

```
Factor     Type Levels Values
Block     fixed      3 1 2 3
Pl Depth  fixed      4 0 cm       10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con  fixed      5 Cutlass          Hoe              Knapsack Sprayer
                       No Weed Control  Weed Wiper

Analysis of Variance for Pen Res, using Adjusted SS for Tests
Source              DF     Seq SS     Adj SS     Adj MS      F      P
Block                2     513422     513422     256711  427.36  0.000
Pl Depth             3      13976      13976       4659    7.76  0.000
Weed Con             4       3157       3157        789    1.31  0.282
Pl Depth*Weed Con   12       4647       4647        387    0.64  0.791
Error               38      22826      22826        601
Total               59     558027

Unusual Observations for Pen Res
Obs    Pen Res       Fit       SE Fit  Residual   St Resid
 32    300.680   252.509       14.841    48.171      2.47R
 43    316.370   272.143       14.841    44.227      2.27R
 52    200.370   252.363       14.841   -51.993     -2.67R

R denotes an observation with a large standardized residual.

Least Squares Means for Pen Res
  Pl Depth                          Mean   SE Mean
0 cm                               343.3     6.328
10 - 15 cm                         303.5     6.328
15 - 20 cm                         309.1     6.328
20 - 25 cm                         316.7     6.328
        Weed Con
Cutlass                            319.7     7.075
Hoe                                324.8     7.075
Knapsack Sprayer                   314.3     7.075
No Weed Control                    306.2     7.075
Weed Wiper                         325.8     7.075

  Pl Depth*        Weed Con
0 cm       Cutlass              337.6    14.150
0 cm       Hoe                  354.4    14.150
0 cm       Knapsack Sprayer     341.7    14.150
0 cm       No Weed Control      337.6    14.150
0 cm       Weed Wiper           345.2    14.150
10 - 15 cm Cutlass              294.5    14.150
10 - 15 cm Hoe                  301.1    14.150
10 - 15 cm Knapsack Sprayer     293.6    14.150
10 - 15 cm No Weed Control      308.4    14.150
10 - 15 cm Weed Wiper           319.8    14.150
```

15 - 20 cm Cutlass	308.2	14.150
15 - 20 cm Hoe	317.8	14.150
15 - 20 cm Knapsack Sprayer	313.5	14.150
15 - 20 cm No Weed Control	287.7	14.150
15 - 20 cm Weed Wiper	318.2	14.150
20 - 25 cm Cutlass	338.4	14.150
20 - 25 cm Hoe	325.9	14.150
20 - 25 cm Knapsack Sprayer	308.2	14.150
20 - 25 cm No Weed Control	291.1	14.150
20 - 25 cm Weed Wiper	320.0	14.150

MINITAB STATISTICAL SOFTWARE OUTPUT: BULK DENSITY (0 – 15 cm)

20th May, 2009.

General Linear Model: Bulk Density versus Block, Pl Depth (cm), ...

Factor	Type	Levels	Values
Block	fixed	3	1 2 3
Pl Depth	fixed	4	0 cm 10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con	fixed	5	Cutlass Hoe Knapsack Sprayer No Weed Control Weed Wiper

Analysis of Variance for Bulk Den, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	0.20658	0.20658	0.10329	7.16	0.002
Pl Depth	3	0.01479	0.01479	0.00493	0.34	0.795
Weed Con	4	0.01449	0.01449	0.00362	0.25	0.907
Pl Depth*Weed Con	12	0.06562	0.06562	0.00547	0.38	0.963
Error	38	0.54782	0.54782	0.01442		
Total	59	0.84930				

Unusual Observations for Bulk Den

Obs	Bulk Den	Fit	SE Fit	Residual	St Resid
19	1.21000	1.42917	0.07270	-0.21917	-2.29R
49	1.15000	1.34417	0.07270	-0.19417	-2.03R

R denotes an observation with a large standardized residual.

Least Squares Means for Bulk Den

Pl Depth	Mean	SE Mean
0 cm	1.362	0.03100
10 - 15 cm	1.373	0.03100
15 - 20 cm	1.371	0.03100
20 - 25 cm	1.334	0.03100
Weed Con		
Cutlass	1.368	0.03466
Hoe	1.329	0.03466
Knapsack Sprayer	1.369	0.03466
No Weed Control	1.368	0.03466
Weed Wiper	1.366	0.03466

Pl Depth*	Weed Con		
0 cm	Cutlass	1.377	0.06932
0 cm	Hoe	1.337	0.06932
0 cm	Knapsack Sprayer	1.340	0.06932
0 cm	No Weed Control	1.380	0.06932
0 cm	Weed Wiper	1.377	0.06932
10 - 15 cm	Cutlass	1.407	0.06932
10 - 15 cm	Hoe	1.410	0.06932
10 - 15 cm	Knapsack Sprayer	1.370	0.06932
10 - 15 cm	No Weed Control	1.347	0.06932
10 - 15 cm	Weed Wiper	1.333	0.06932
15 - 20 cm	Cutlass	1.410	0.06932
15 - 20 cm	Hoe	1.280	0.06932
15 - 20 cm	Knapsack Sprayer	1.377	0.06932
15 - 20 cm	No Weed Control	1.400	0.06932
15 - 20 cm	Weed Wiper	1.390	0.06932
20 - 25 cm	Cutlass	1.280	0.06932

20 - 25 cm Hoe	1.290	0.06932
20 - 25 cm Knapsack Sprayer	1.390	0.06932
20 - 25 cm No Weed Control	1.347	0.06932
20 - 25 cm Weed Wiper	1.363	0.06932

5th August, 2009.

General Linear Model: Bulk Density versus Block, Pl Depth (cm), ...

Factor	Type	Levels	Values
Block	fixed	3	1 2 3
Pl Depth	fixed	4	0 cm 10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con	fixed	5	Cutlass Hoe Knapsack Sprayer No Weed Control Weed Wiper

Analysis of Variance for Bulk Den, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	0.048160	0.048160	0.024080	3.68	0.035
Pl Depth	3	0.106480	0.106480	0.035493	5.42	0.003
Weed Con	4	0.040423	0.040423	0.010106	1.54	0.209
Pl Depth*Weed Con	12	0.073137	0.073137	0.006095	0.93	0.527
Error	38	0.248840	0.248840	0.006548		
Total	59	0.517040				

Unusual Observations for Bulk Den

Obs	Bulk Den	Fit	SE Fit	Residual	St Resid
20	1.22000	1.38467	0.04900	-0.16467	-2.56R
27	1.14000	1.36533	0.04900	-0.22533	-3.50R
48	1.46000	1.32000	0.04900	0.14000	2.17R

R denotes an observation with a large standardized residual.

Least Squares Means for Bulk Den

Pl Depth	Mean	SE Mean
0 cm	1.403	0.02089
10 - 15 cm	1.414	0.02089
15 - 20 cm	1.407	0.02089
20 - 25 cm	1.311	0.02089
Weed Con		
Cutlass	1.357	0.02336
Hoe	1.378	0.02336
Knapsack Sprayer	1.418	0.02336
No Weed Control	1.357	0.02336
Weed Wiper	1.411	0.02336

Pl Depth*	Weed Con		
0 cm	Cutlass	1.407	0.04672
0 cm	Hoe	1.430	0.04672
0 cm	Knapsack Sprayer	1.420	0.04672
0 cm	No Weed Control	1.300	0.04672
0 cm	Weed Wiper	1.460	0.04672
10 - 15 cm	Cutlass	1.360	0.04672
10 - 15 cm	Hoe	1.343	0.04672
10 - 15 cm	Knapsack Sprayer	1.440	0.04672
10 - 15 cm	No Weed Control	1.447	0.04672
10 - 15 cm	Weed Wiper	1.480	0.04672
15 - 20 cm	Cutlass	1.383	0.04672
15 - 20 cm	Hoe	1.407	0.04672
15 - 20 cm	Knapsack Sprayer	1.443	0.04672
15 - 20 cm	No Weed Control	1.413	0.04672
15 - 20 cm	Weed Wiper	1.390	0.04672
20 - 25 cm	Cutlass	1.277	0.04672
20 - 25 cm	Hoe	1.333	0.04672
20 - 25 cm	Knapsack Sprayer	1.367	0.04672
20 - 25 cm	No Weed Control	1.267	0.04672
20 - 25 cm	Weed Wiper	1.313	0.04672

5th October, 2009.

General Linear Model: Bulk Density versus Block, Pl Depth (cm), ...

Factor	Type	Levels	Values
Block	fixed	3	1 2 3
Pl Depth	fixed	4	0 cm 10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con	fixed	5	Cutlass Hoe Knapsack Sprayer No Weed Control Weed Wiper

Analysis of Variance for Bulk Den, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	0.05356	0.05356	0.02678	1.46	0.245
Pl Depth	3	0.05189	0.05189	0.01730	0.94	0.430
Weed Con	4	0.04457	0.04457	0.01114	0.61	0.660
Pl Depth*Weed Con	12	0.03777	0.03777	0.00315	0.17	0.999
Error	38	0.69724	0.69724	0.01835		
Total	59	0.88504				

Least Squares Means for Bulk Den

Pl Depth	Mean	SE Mean
0 cm	1.366	0.03497
10 - 15 cm	1.303	0.03497
15 - 20 cm	1.373	0.03497
20 - 25 cm	1.374	0.03497
Weed Con		
Cutlass	1.331	0.03910
Hoe	1.388	0.03910
Knapsack Sprayer	1.384	0.03910
No Weed Control	1.323	0.03910
Weed Wiper	1.344	0.03910

Pl Depth*	Weed Con	Mean	SE Mean
0 cm	Cutlass	1.300	0.07821
0 cm	Hoe	1.447	0.07821
0 cm	Knapsack Sprayer	1.427	0.07821
0 cm	No Weed Control	1.297	0.07821
0 cm	Weed Wiper	1.360	0.07821
10 - 15 cm	Cutlass	1.287	0.07821
10 - 15 cm	Hoe	1.293	0.07821
10 - 15 cm	Knapsack Sprayer	1.313	0.07821
10 - 15 cm	No Weed Control	1.313	0.07821
10 - 15 cm	Weed Wiper	1.310	0.07821
15 - 20 cm	Cutlass	1.380	0.07821
15 - 20 cm	Hoe	1.393	0.07821
15 - 20 cm	Knapsack Sprayer	1.403	0.07821
15 - 20 cm	No Weed Control	1.330	0.07821
15 - 20 cm	Weed Wiper	1.357	0.07821
20 - 25 cm	Cutlass	1.357	0.07821
20 - 25 cm	Hoe	1.420	0.07821
20 - 25 cm	Knapsack Sprayer	1.393	0.07821
20 - 25 cm	No Weed Control	1.350	0.07821
20 - 25 cm	Weed Wiper	1.350	0.07821

MINITAB STATISTICAL SOFTWARE OUTPUT: BULK DENSITY (15 – 30 cm)

20th May, 2009.

General Linear Model: Bulk Density versus Block, Ploughing Depth , ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth (cm)	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Bulk Density, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	0.12027	0.12027	0.06013	3.57	0.038
Ploughing Depth (cm)	3	0.08034	0.08034	0.02678	1.59	0.207
Weed Control	4	0.00716	0.00716	0.00179	0.11	0.980
Ploughing Depth (cm)*Weed Control	12	0.09854	0.09854	0.00821	0.49	0.909

```
Error                              38  0.63946  0.63946  0.01683
Total                              59  0.94576

S = 0.129723   R-Sq = 32.39%   R-Sq(adj) = 0.00%

Least Squares Means for Bulk Density
Ploughing De                        Mean  SE Mean
0 cm                               1.369  0.03349
10 - 15 cm                         1.349  0.03349
15 - 20 cm                         1.296  0.03349
20 - 25 cm                         1.280  0.03349
Weed Control
Cutlass                            1.335  0.03745
Hoe                                1.309  0.03745
Knapsack Sprayer                   1.318  0.03745
No Weed Control                    1.338  0.03745
Weed Wiper                         1.318  0.03745
Ploughing De*Weed Control
0 cm          Cutlass              1.347  0.07490
0 cm          Hoe                  1.397  0.07490
0 cm          Knapsack Sprayer     1.417  0.07490
0 cm          No Weed Control      1.313  0.07490
0 cm          Weed Wiper           1.370  0.07490
10 - 15 cm    Cutlass              1.363  0.07490
10 - 15 cm    Hoe                  1.343  0.07490
10 - 15 cm    Knapsack Sprayer     1.320  0.07490
10 - 15 cm    No Weed Control      1.400  0.07490
10 - 15 cm    Weed Wiper           1.320  0.07490
15 - 20 cm    Cutlass              1.307  0.07490
15 - 20 cm    Hoe                  1.270  0.07490
15 - 20 cm    Knapsack Sprayer     1.217  0.07490
15 - 20 cm    No Weed Control      1.320  0.07490
15 - 20 cm    Weed Wiper           1.367  0.07490
20 - 25 cm    Cutlass              1.323  0.07490
20 - 25 cm    Hoe                  1.227  0.07490
20 - 25 cm    Knapsack Sprayer     1.317  0.07490
20 - 25 cm    No Weed Control      1.317  0.07490
20 - 25 cm    Weed Wiper           1.217  0.07490
```

5th August, 2009.

General Linear Model: Bulk Density versus Block, Pl Depth (cm), ...

```
Factor     Type Levels Values
Block     fixed      3 1 2 3
Pl Depth  fixed      4 0 cm        10 - 15 cm 15 - 20 cm 20 - 25 cm
Weed Con  fixed      5 Cutlass          Hoe              Knapsack Sprayer
                       No Weed Control  Weed Wiper

Analysis of Variance for Bulk Den, using Adjusted SS for Tests
Source               DF     Seq SS     Adj SS     Adj MS       F      P
Block                 2   0.062583   0.062583   0.031292    3.97  0.027
Pl Depth              3   0.223893   0.223893   0.074631    9.46  0.000
Weed Con              4   0.069117   0.069117   0.017279    2.19  0.089
Pl Depth*Weed Con    12   0.057657   0.057657   0.004805    0.61  0.821
Error                38   0.299883   0.299883   0.007892
Total                59   0.713133

Unusual Observations for Bulk Den
Obs  Bulk Den        Fit      SE Fit  Residual   St Resid
 28   1.26000    1.41667     0.05379  -0.15667     -2.22R
 43   1.16000    1.32917     0.05379  -0.16917     -2.39R
 48   1.50000    1.33917     0.05379   0.16083      2.27R

R denotes an observation with a large standardized residual.

Least Squares Means for Bulk Den
  Pl Depth                          Mean   SE Mean
0 cm                               1.410   0.02294
```

10 - 15 cm	1.405	0.02294
15 - 20 cm	1.421	0.02294
20 - 25 cm	1.271	0.02294
Weed Con		
Cutlass	1.339	0.02564
Hoe	1.407	0.02564
Knapsack Sprayer	1.412	0.02564
No Weed Control	1.333	0.02564
Weed Wiper	1.393	0.02564

Pl Depth*	Weed Con		
0 cm	Cutlass	1.363	0.05129
0 cm	Hoe	1.477	0.05129
0 cm	Knapsack Sprayer	1.457	0.05129
0 cm	No Weed Control	1.313	0.05129
0 cm	Weed Wiper	1.440	0.05129
10 - 15 cm	Cutlass	1.373	0.05129
10 - 15 cm	Hoe	1.383	0.05129
10 - 15 cm	Knapsack Sprayer	1.430	0.05129
10 - 15 cm	No Weed Control	1.377	0.05129
10 - 15 cm	Weed Wiper	1.460	0.05129
15 - 20 cm	Cutlass	1.437	0.05129
15 - 20 cm	Hoe	1.423	0.05129
15 - 20 cm	Knapsack Sprayer	1.453	0.05129
15 - 20 cm	No Weed Control	1.387	0.05129
15 - 20 cm	Weed Wiper	1.403	0.05129
20 - 25 cm	Cutlass	1.183	0.05129
20 - 25 cm	Hoe	1.343	0.05129
20 - 25 cm	Knapsack Sprayer	1.307	0.05129
20 - 25 cm	No Weed Control	1.253	0.05129
20 - 25 cm	Weed Wiper	1.270	0.05129

5th October, 2009.

General Linear Model: Bulk Density versus Block, Pl Depth (cm), ...

Factor	Type	Levels	Values
Block	fixed	3	1 2 3
Pl Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Con	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Bulk Den, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	0.21896	0.21896	0.10948	3.39	0.044
Pl Depth	3	0.06886	0.06886	0.02295	0.71	0.551
Weed Con	4	0.04108	0.04108	0.01027	0.32	0.864
Pl Depth*Weed Con	12	0.09736	0.09736	0.00811	0.25	0.993
Error	38	1.22577	1.22577	0.03226		
Total	59	1.65203				

Unusual Observations for Bulk Den

Obs	Bulk Den	Fit	SE Fit	Residual	St Resid
46	1.55000	1.25283	0.10875	0.29717	2.08R
48	1.50000	1.20950	0.10875	0.29050	2.03R

R denotes an observation with a large standardized residual.

Least Squares Means for Bulk Den

Pl Depth	Mean	SE Mean
0 cm	1.328	0.04637
10 - 15 cm	1.328	0.04637
15 - 20 cm	1.390	0.04637
20 - 25 cm	1.401	0.04637
Weed Con		
Cutlass	1.332	0.05185
Hoe	1.401	0.05185
Knapsack Sprayer	1.383	0.05185
No Weed Control	1.352	0.05185
Weed Wiper	1.340	0.05185

```
  Pl Depth*        Weed Con
0 cm        Cutlass              1.217   0.10369
0 cm        Hoe                  1.400   0.10369
0 cm        Knapsack Sprayer     1.420   0.10369
0 cm        No Weed Control      1.277   0.10369
0 cm        Weed Wiper           1.327   0.10369
10 - 15 cm Cutlass               1.287   0.10369
10 - 15 cm Hoe                   1.353   0.10369
10 - 15 cm Knapsack Sprayer      1.333   0.10369
10 - 15 cm No Weed Control       1.330   0.10369
10 - 15 cm Weed Wiper            1.337   0.10369
15 - 20 cm Cutlass               1.433   0.10369
15 - 20 cm Hoe                   1.393   0.10369
15 - 20 cm Knapsack Sprayer      1.423   0.10369
15 - 20 cm No Weed Control       1.360   0.10369
15 - 20 cm Weed Wiper            1.340   0.10369
20 - 25 cm Cutlass               1.393   0.10369
20 - 25 cm Hoe                   1.457   0.10369
20 - 25 cm Knapsack Sprayer      1.357   0.10369
20 - 25 cm No Weed Control       1.440   0.10369
20 - 25 cm Weed Wiper            1.357   0.10369
```

MOISTURE CONTENT (%)

20th May, 2009. **(0 – 15 cm)**

General Linear Model: Moisture Content versus Block, Pl Depth (cm), ...

```
Factor          Type   Levels  Values
Block           fixed       3  1, 2, 3
Pl Depth (cm)   fixed       4  0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control    fixed       5  Cutlass, Hoe, Knapsack Sprayer, No Weed Control,
                               Weed Wiper

Analysis of Variance for Moisture Content (%), using Adjusted SS for Tests
Source                       DF   Seq SS   Adj SS  Adj MS     F      P
Block                         2   25.060   25.060  12.530  4.49  0.018
Pl Depth (cm)                 3    4.700    4.700   1.567  0.56  0.644
Weed Control                  4    9.171    9.171   2.293  0.82  0.520
Pl Depth (cm)*Weed Control   12   19.549   19.549   1.629  0.58  0.842
Error                        38  106.095  106.095   2.792
Total                        59  164.575

S = 1.67092   R-Sq = 35.53%   R-Sq(adj) = 0.00%

Unusual Observations for Moisture Content (%)
        Moisture
Obs  Content (%)      Fit  SE Fit  Residual  St Resid
 29      17.2900  12.1115  1.0118    5.1785      3.89 R
 49       7.3700  10.5925  1.0118   -3.2225     -2.42 R

R denotes an observation with a large standardized residual.

Least Squares Means for Moisture Content (%)
Pl Depth (cm                        Mean  SE Mean
0 cm                              10.214   0.4314
10 - 15 cm                         9.751   0.4314
15 - 20 cm                         9.805   0.4314
20 - 25 cm                        10.421   0.4314
Weed Control
Cutlass                           10.150   0.4824
Hoe                                9.637   0.4824
Knapsack Sprayer                  10.746   0.4824
No Weed Control                    9.748   0.4824
Weed Wiper                         9.958   0.4824
Pl Depth (cm*Weed Control
0 cm          Cutlass             11.180   0.9647
0 cm          Hoe                  9.887   0.9647
0 cm          Knapsack Sprayer    10.273   0.9647
```

0 cm	No Weed Control	10.123	0.9647
0 cm	Weed Wiper	9.607	0.9647
10 - 15 cm	Cutlass	9.243	0.9647
10 - 15 cm	Hoe	8.747	0.9647
10 - 15 cm	Knapsack Sprayer	10.110	0.9647
10 - 15 cm	No Weed Control	9.433	0.9647
10 - 15 cm	Weed Wiper	11.223	0.9647
15 - 20 cm	Cutlass	9.477	0.9647
15 - 20 cm	Hoe	9.593	0.9647
15 - 20 cm	Knapsack Sprayer	11.337	0.9647
15 - 20 cm	No Weed Control	9.237	0.9647
15 - 20 cm	Weed Wiper	9.383	0.9647
20 - 25 cm	Cutlass	10.700	0.9647
20 - 25 cm	Hoe	10.323	0.9647
20 - 25 cm	Knapsack Sprayer	11.263	0.9647
20 - 25 cm	No Weed Control	10.197	0.9647
20 - 25 cm	Weed Wiper	9.620	0.9647

5th August, 2009.

General Linear Model: MC, % versus Block, Ploughing Depth, Weed Control

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for MC, %, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	21.868	21.868	10.934	7.48	0.002
Ploughing Depth	3	9.987	9.987	3.329	2.28	0.095
Weed Control	4	14.257	14.257	3.564	2.44	0.063
Ploughing Depth*Weed Control	12	28.221	28.221	2.352	1.61	0.130
Error	38	55.520	55.520	1.461		
Total	59	129.853				

S = 1.20875   R-Sq = 57.24%   R-Sq(adj) = 33.62%

Unusual Observations for MC, %

Obs	MC, %	Fit	SE Fit	Residual	St Resid
29	15.1600	13.2137	0.7319	1.9463	2.02 R
50	17.7200	14.9610	0.7319	2.7590	2.87 R

R denotes an observation with a large standardized residual.

Least Squares Means for MC, %

Ploughing De		Mean	SE Mean
0 cm		11.57	0.3121
10 - 15 cm		12.31	0.3121
15 - 20 cm		11.71	0.3121
20 - 25 cm		12.55	0.3121
Weed Control			
Cutlass		12.32	0.3489
Hoe		11.57	0.3489
Knapsack Sprayer		12.71	0.3489
No Weed Control		11.40	0.3489
Weed Wiper		12.17	0.3489
Ploughing De*Weed Control			
0 cm	Cutlass	12.41	0.6979
0 cm	Hoe	11.44	0.6979
0 cm	Knapsack Sprayer	11.43	0.6979
0 cm	No Weed Control	11.41	0.6979
0 cm	Weed Wiper	11.16	0.6979
10 - 15 cm	Cutlass	12.04	0.6979
10 - 15 cm	Hoe	10.48	0.6979
10 - 15 cm	Knapsack Sprayer	14.14	0.6979
10 - 15 cm	No Weed Control	11.44	0.6979

10 - 15 cm	Weed Wiper	13.43	0.6979
15 - 20 cm	Cutlass	11.35	0.6979
15 - 20 cm	Hoe	11.70	0.6979
15 - 20 cm	Knapsack Sprayer	13.14	0.6979
15 - 20 cm	No Weed Control	10.77	0.6979
15 - 20 cm	Weed Wiper	11.57	0.6979
20 - 25 cm	Cutlass	13.49	0.6979
20 - 25 cm	Hoe	12.63	0.6979
20 - 25 cm	Knapsack Sprayer	12.15	0.6979
20 - 25 cm	No Weed Control	11.98	0.6979
20 - 25 cm	Weed Wiper	12.52	0.6979

5th October, 2009.

General Linear Model: MC (%) versus Block, Ploughing Depth, Weed Control

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for MC (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	204.144	204.144	102.072	40.79	0.000
Ploughing Depth	3	24.616	24.616	8.205	3.28	0.031
Weed Control	4	16.066	16.066	4.017	1.61	0.193
Ploughing Depth*Weed Control	12	46.074	46.074	3.840	1.53	0.155
Error	38	95.090	95.090	2.502		
Total	59	385.991				

S = 1.58189   R-Sq = 75.36%   R-Sq(adj) = 61.75%

Unusual Observations for MC (%)

Obs	MC (%)	Fit	SE Fit	Residual	St Resid
56	17.5700	14.9955	0.9579	2.5745	2.05 R

R denotes an observation with a large standardized residual.

Least Squares Means for MC (%)

Ploughing De		Mean	SE Mean
0 cm		11.94	0.4084
10 - 15 cm		13.38	0.4084
15 - 20 cm		13.26	0.4084
20 - 25 cm		13.56	0.4084
Weed Control			
Cutlass		13.36	0.4567
Hoe		12.87	0.4567
Knapsack Sprayer		13.86	0.4567
No Weed Control		12.38	0.4567
Weed Wiper		12.71	0.4567
Ploughing De*Weed Control			
0 cm	Cutlass	12.59	0.9133
0 cm	Hoe	12.12	0.9133
0 cm	Knapsack Sprayer	12.14	0.9133
0 cm	No Weed Control	11.07	0.9133
0 cm	Weed Wiper	11.78	0.9133
10 - 15 cm	Cutlass	13.20	0.9133
10 - 15 cm	Hoe	11.84	0.9133
10 - 15 cm	Knapsack Sprayer	14.89	0.9133
10 - 15 cm	No Weed Control	13.07	0.9133
10 - 15 cm	Weed Wiper	13.88	0.9133
15 - 20 cm	Cutlass	12.55	0.9133
15 - 20 cm	Hoe	13.60	0.9133
15 - 20 cm	Knapsack Sprayer	15.77	0.9133
15 - 20 cm	No Weed Control	11.65	0.9133
15 - 20 cm	Weed Wiper	12.73	0.9133
20 - 25 cm	Cutlass	15.09	0.9133
20 - 25 cm	Hoe	13.91	0.9133

20 - 25 cm	Knapsack Sprayer	12.62	0.9133
20 - 25 cm	No Weed Control	13.74	0.9133
20 - 25 cm	Weed Wiper	12.44	0.9133

MINITAB STATISTICAL SOFTWARE OUTPUT: MOISTURE CONTENT (15– 30 cm)

20th May, 2009.

General Linear Model: Moisture Content versus Block, Pl Depth (cm), ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Pl Depth (cm)	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Moisture Content (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	9.396	9.396	4.698	1.83	0.174
Pl Depth (cm)	3	9.071	9.071	3.024	1.18	0.331
Weed Control	4	2.518	2.518	0.629	0.25	0.911
Pl Depth (cm)*Weed Control	12	45.103	45.103	3.759	1.46	0.181
Error	38	97.605	97.605	2.569		
Total	59	163.693				

S = 1.60267   R-Sq = 40.37%   R-Sq(adj) = 7.42%

Unusual Observations for Moisture Content (%)

Obs	Moisture Content (%)	Fit	SE Fit	Residual	St Resid	
24	7.1800	9.9385	0.9705	-2.7585	-2.16	R
40	12.1400	9.3318	0.9705	2.8082	2.20	R
60	4.6100	8.3873	0.9705	-3.7773	-2.96	R

R denotes an observation with a large standardized residual.

Least Squares Means for Moisture Content (%)

Pl Depth (cm		Mean	SE Mean
0 cm		9.338	0.4138
10 - 15 cm		9.521	0.4138
15 - 20 cm		10.040	0.4138
20 - 25 cm		10.306	0.4138
Weed Control			
Cutlass		9.715	0.4627
Hoe		10.002	0.4627
Knapsack Sprayer		10.068	0.4627
No Weed Control		9.707	0.4627
Weed Wiper		9.515	0.4627
Pl Depth (cm*Weed Control			
0 cm	Cutlass	10.037	0.9253
0 cm	Hoe	8.987	0.9253
0 cm	Knapsack Sprayer	8.677	0.9253
0 cm	No Weed Control	9.587	0.9253
0 cm	Weed Wiper	9.403	0.9253
10 - 15 cm	Cutlass	7.917	0.9253
10 - 15 cm	Hoe	10.037	0.9253
10 - 15 cm	Knapsack Sprayer	10.717	0.9253
10 - 15 cm	No Weed Control	9.823	0.9253
10 - 15 cm	Weed Wiper	9.113	0.9253
15 - 20 cm	Cutlass	9.580	0.9253
15 - 20 cm	Hoe	10.513	0.9253
15 - 20 cm	Knapsack Sprayer	12.083	0.9253
15 - 20 cm	No Weed Control	8.820	0.9253
15 - 20 cm	Weed Wiper	9.203	0.9253
20 - 25 cm	Cutlass	11.327	0.9253
20 - 25 cm	Hoe	10.470	0.9253
20 - 25 cm	Knapsack Sprayer	8.797	0.9253
20 - 25 cm	No Weed Control	10.597	0.9253
20 - 25 cm	Weed Wiper	10.340	0.9253

5th August, 2009.

General Linear Model: Moisture Con versus Block, Ploughing De, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth (cm)	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Moisture Content (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	32.532	32.532	16.266	6.87	0.003
Ploughing Depth (cm)	3	19.394	19.394	6.465	2.73	0.057
Weed Control	4	39.535	39.535	9.884	4.17	0.007
Ploughing Depth (cm)*Weed Control	12	40.222	40.222	3.352	1.41	0.202
Error	38	90.015	90.015	2.369		
Total	59	221.697				

S = 1.53909   R-Sq = 59.40%   R-Sq(adj) = 36.96%

Unusual Observations for Moisture Content (%)

Obs	Moisture Content (%)	Fit	SE Fit	Residual	St Resid
1	7.3400	9.8217	0.9320	-2.4817	-2.03 R
23	16.2000	12.9565	0.9320	3.2435	2.65 R
29	15.4800	12.7098	0.9320	2.7702	2.26 R

R denotes an observation with a large standardized residual.

Least Squares Means for Moisture Content (%)

Ploughing De		Mean	SE Mean
0 cm		11.751	0.3974
10 - 15 cm		11.247	0.3974
15 - 20 cm		10.825	0.3974
20 - 25 cm		12.347	0.3974
Weed Control			
Cutlass		11.787	0.4443
Hoe		10.973	0.4443
Knapsack Sprayer		12.799	0.4443
No Weed Control		10.407	0.4443
Weed Wiper		11.747	0.4443
Ploughing De*Weed Control			
0 cm	Cutlass	12.970	0.8886
0 cm	Hoe	11.387	0.8886
0 cm	Knapsack Sprayer	12.127	0.8886
0 cm	No Weed Control	10.717	0.8886
0 cm	Weed Wiper	11.553	0.8886
10 - 15 cm	Cutlass	9.877	0.8886
10 - 15 cm	Hoe	9.743	0.8886
10 - 15 cm	Knapsack Sprayer	14.063	0.8886
10 - 15 cm	No Weed Control	9.827	0.8886
10 - 15 cm	Weed Wiper	12.723	0.8886
15 - 20 cm	Cutlass	10.557	0.8886
15 - 20 cm	Hoe	11.113	0.8886
15 - 20 cm	Knapsack Sprayer	12.287	0.8886
15 - 20 cm	No Weed Control	9.427	0.8886
15 - 20 cm	Weed Wiper	10.743	0.8886
20 - 25 cm	Cutlass	13.743	0.8886
20 - 25 cm	Hoe	11.650	0.8886
20 - 25 cm	Knapsack Sprayer	12.720	0.8886
20 - 25 cm	No Weed Control	11.657	0.8886
20 - 25 cm	Weed Wiper	11.967	0.8886

5th October, 2009.

General Linear Model: MC, % versus Block, Ploughing Depth, Weed Control

Factor	Type	Levels	Values

Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for MC, %, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	30.270	30.270	15.135	6.66	0.003
Ploughing Depth	3	46.444	46.444	15.481	6.81	0.001
Weed Control	4	20.726	20.726	5.182	2.28	0.079
Ploughing Depth*Weed Control	12	28.466	28.466	2.372	1.04	0.432
Error	38	86.409	86.409	2.274		
Total	59	212.315				

S = 1.50795   R-Sq = 59.30%   R-Sq(adj) = 36.81%

Unusual Observations for MC, %

Obs	MC, %	Fit	SE Fit	Residual	St Resid	
15	17.0100	13.9373	0.9131	3.0727	2.56	R
22	16.4300	14.0050	0.9131	2.4250	2.02	R
55	12.3200	15.1043	0.9131	-2.7843	-2.32	R

R denotes an observation with a large standardized residual.

Least Squares Means for MC, %

Ploughing De		Mean	SE Mean
0 cm		12.84	0.3894
10 - 15 cm		12.11	0.3894
15 - 20 cm		13.45	0.3894
20 - 25 cm		14.51	0.3894
Weed Control			
Cutlass		13.04	0.4353
Hoe		13.42	0.4353
Knapsack Sprayer		13.95	0.4353
No Weed Control		12.21	0.4353
Weed Wiper		13.53	0.4353
Ploughing De*Weed Control			
0 cm	Cutlass	13.04	0.8706
0 cm	Hoe	13.26	0.8706
0 cm	Knapsack Sprayer	12.83	0.8706
0 cm	No Weed Control	12.05	0.8706
0 cm	Weed Wiper	13.02	0.8706
10 - 15 cm	Cutlass	12.18	0.8706
10 - 15 cm	Hoe	11.89	0.8706
10 - 15 cm	Knapsack Sprayer	12.01	0.8706
10 - 15 cm	No Weed Control	11.10	0.8706
10 - 15 cm	Weed Wiper	13.36	0.8706
15 - 20 cm	Cutlass	12.92	0.8706
15 - 20 cm	Hoe	14.24	0.8706
15 - 20 cm	Knapsack Sprayer	14.89	0.8706
15 - 20 cm	No Weed Control	11.05	0.8706
15 - 20 cm	Weed Wiper	14.16	0.8706
20 - 25 cm	Cutlass	14.01	0.8706
20 - 25 cm	Hoe	14.27	0.8706
20 - 25 cm	Knapsack Sprayer	16.06	0.8706
20 - 25 cm	No Weed Control	14.63	0.8706
20 - 25 cm	Weed Wiper	13.58	0.8706

MINITAB STATISTICAL SOFTWARE OUTPUT: POROSITY (0 – 15 cm)

20th May, 2009.

General Linear Model: Porosity, % versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Porosity, %, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	284.23	284.23	142.12	7.19	0.002
Ploughing Depth	3	20.58	20.58	6.86	0.35	0.791
Weed Control	4	27.40	27.40	6.85	0.35	0.845
Ploughing Depth*Weed Control	12	101.67	101.67	8.47	0.43	0.942
Error	38	751.10	751.10	19.77		
Total	59	1184.98				

S = 4.44587   R-Sq = 36.62%   R-Sq(adj) = 1.59%

Unusual Observations for Porosity, %

Obs	Porosity, %	Fit	SE Fit	Residual	St Resid
19	54.0000	46.1833	2.6921	7.8167	2.21 R
49	57.0000	49.6667	2.6921	7.3333	2.07 R

R denotes an observation with a large standardized residual.

Least Squares Means for Porosity, %

Ploughing De	Mean	SE Mean
0 cm	49.00	1.148
10 - 15 cm	48.47	1.148
15 - 20 cm	48.53	1.148
20 - 25 cm	49.93	1.148

Weed Control		
Cutlass	48.58	1.283
Hoe	50.33	1.283
Knapsack Sprayer	48.67	1.283
No Weed Control	48.67	1.283
Weed Wiper	48.67	1.283

Ploughing De*Weed Control			
0 cm	Cutlass	48.00	2.567
0 cm	Hoe	50.00	2.567
0 cm	Knapsack Sprayer	50.00	2.567
0 cm	No Weed Control	48.33	2.567
0 cm	Weed Wiper	48.67	2.567
10 - 15 cm	Cutlass	47.33	2.567
10 - 15 cm	Hoe	47.33	2.567
10 - 15 cm	Knapsack Sprayer	48.33	2.567
10 - 15 cm	No Weed Control	49.33	2.567
10 - 15 cm	Weed Wiper	50.00	2.567
15 - 20 cm	Cutlass	47.00	2.567
15 - 20 cm	Hoe	52.33	2.567
15 - 20 cm	Knapsack Sprayer	48.67	2.567
15 - 20 cm	No Weed Control	47.33	2.567
15 - 20 cm	Weed Wiper	47.33	2.567
20 - 25 cm	Cutlass	52.00	2.567
20 - 25 cm	Hoe	51.67	2.567
20 - 25 cm	Knapsack Sprayer	47.67	2.567
20 - 25 cm	No Weed Control	49.67	2.567
20 - 25 cm	Weed Wiper	48.67	2.567

5th August, 2009.

General Linear Model: Porosity, % versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Porosity, %, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	86.23	86.23	43.12	0.74	0.482
Ploughing Depth	3	164.40	164.40	54.80	0.94	0.429
Weed Control	4	139.90	139.90	34.98	0.60	0.663

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Ploughing Depth*Weed Control	12	502.77	502.77	41.90	0.72	0.721
Error	38	2204.43	2204.43	58.01		
Total	59	3097.73				

S = 7.61652   R-Sq = 28.84%   R-Sq(adj) = 0.00%

Unusual Observations for Porosity, %

Obs	Porosity, %	Fit	SE Fit	Residual	St Resid
9	97.0000	62.6833	4.6120	34.3167	5.66 R
29	42.0000	59.9833	4.6120	-17.9833	-2.97 R
49	46.0000	62.3333	4.6120	-16.3333	-2.69 R

R denotes an observation with a large standardized residual.

Least Squares Means for Porosity, %

Ploughing De		Mean	SE Mean
0 cm		47.40	1.967
10 - 15 cm		50.20	1.967
15 - 20 cm		47.20	1.967
20 - 25 cm		50.93	1.967
Weed Control			
Cutlass		49.17	2.199
Hoe		48.42	2.199
Knapsack Sprayer		46.58	2.199
No Weed Control		49.17	2.199
Weed Wiper		51.33	2.199
Ploughing De*Weed Control			
0 cm	Cutlass	47.67	4.397
0 cm	Hoe	46.33	4.397
0 cm	Knapsack Sprayer	46.33	4.397
0 cm	No Weed Control	51.33	4.397
0 cm	Weed Wiper	45.33	4.397
10 - 15 cm	Cutlass	48.67	4.397
10 - 15 cm	Hoe	49.67	4.397
10 - 15 cm	Knapsack Sprayer	45.67	4.397
10 - 15 cm	No Weed Control	45.33	4.397
10 - 15 cm	Weed Wiper	61.67	4.397
15 - 20 cm	Cutlass	48.00	4.397
15 - 20 cm	Hoe	47.33	4.397
15 - 20 cm	Knapsack Sprayer	45.67	4.397
15 - 20 cm	No Weed Control	47.33	4.397
15 - 20 cm	Weed Wiper	47.67	4.397
20 - 25 cm	Cutlass	52.33	4.397
20 - 25 cm	Hoe	50.33	4.397
20 - 25 cm	Knapsack Sprayer	48.67	4.397
20 - 25 cm	No Weed Control	52.67	4.397
20 - 25 cm	Weed Wiper	50.67	4.397

5th October, 2009.

General Linear Model: Porosity, % versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Porosity, %, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	82.23	82.23	41.12	1.58	0.218
Ploughing Depth	3	65.25	65.25	21.75	0.84	0.481
Weed Control	4	61.77	61.77	15.44	0.60	0.668
Ploughing Depth*Weed Control	12	55.17	55.17	4.60	0.18	0.999
Error	38	985.77	985.77	25.94		
Total	59	1250.18				

S = 5.09325   R-Sq = 21.15%   R-Sq(adj) = 0.00%

Unusual Observations for Porosity, %

Obs	Porosity, %	Fit	SE Fit	Residual	St Resid
48	45.0000	53.1833	3.0841	-8.1833	-2.02 R

R denotes an observation with a large standardized residual.

Least Squares Means for Porosity, %

Ploughing De		Mean	SE Mean
0 cm		48.93	1.315
10 - 15 cm		51.07	1.315
15 - 20 cm		48.67	1.315
20 - 25 cm		48.47	1.315
Weed Control			
Cutlass		50.08	1.470
Hoe		48.08	1.470
Knapsack Sprayer		48.08	1.470
No Weed Control		50.50	1.470
Weed Wiper		49.67	1.470
Ploughing De*Weed Control			
0 cm	Cutlass	51.33	2.941
0 cm	Hoe	45.67	2.941
0 cm	Knapsack Sprayer	46.67	2.941
0 cm	No Weed Control	51.67	2.941
0 cm	Weed Wiper	49.33	2.941
10 - 15 cm	Cutlass	51.67	2.941
10 - 15 cm	Hoe	51.67	2.941
10 - 15 cm	Knapsack Sprayer	50.33	2.941
10 - 15 cm	No Weed Control	51.00	2.941
10 - 15 cm	Weed Wiper	50.67	2.941
15 - 20 cm	Cutlass	48.33	2.941
15 - 20 cm	Hoe	48.00	2.941
15 - 20 cm	Knapsack Sprayer	47.67	2.941
15 - 20 cm	No Weed Control	50.00	2.941
15 - 20 cm	Weed Wiper	49.33	2.941
20 - 25 cm	Cutlass	49.00	2.941
20 - 25 cm	Hoe	47.00	2.941
20 - 25 cm	Knapsack Sprayer	47.67	2.941
20 - 25 cm	No Weed Control	49.33	2.941
20 - 25 cm	Weed Wiper	49.33	2.941

MINITAB STATISTICAL SOFTWARE OUTPUT: POROSITY (15– 30 cm)

20th May, 2009.

General Linear Model: Porosity, % versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Porosity, %, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	180.63	180.63	90.32	3.74	0.033
Ploughing Depth	3	112.85	112.85	37.62	1.56	0.215
Weed Control	4	13.00	13.00	3.25	0.13	0.969
Ploughing Depth*Weed Control	12	140.73	140.73	11.73	0.49	0.910
Error	38	917.37	917.37	24.14		
Total	59	1364.58				

S = 4.91337   R-Sq = 32.77%   R-Sq(adj) = 0.00%

Least Squares Means for Porosity, %

Ploughing De	Mean	SE Mean
0 cm	48.73	1.269
10 - 15 cm	49.47	1.269

15 - 20 cm		51.33	1.269
20 - 25 cm		52.13	1.269
Weed Control			
Cutlass		50.00	1.418
Hoe		51.00	1.418
Knapsack Sprayer		50.67	1.418
No Weed Control		49.75	1.418
Weed Wiper		50.67	1.418
Ploughing De*Weed Control			
0 cm	Cutlass	49.67	2.837
0 cm	Hoe	47.67	2.837
0 cm	Knapsack Sprayer	47.00	2.837
0 cm	No Weed Control	50.67	2.837
0 cm	Weed Wiper	48.67	2.837
10 - 15 cm	Cutlass	48.67	2.837
10 - 15 cm	Hoe	49.67	2.837
10 - 15 cm	Knapsack Sprayer	51.00	2.837
10 - 15 cm	No Weed Control	47.33	2.837
10 - 15 cm	Weed Wiper	50.67	2.837
15 - 20 cm	Cutlass	51.00	2.837
15 - 20 cm	Hoe	52.67	2.837
15 - 20 cm	Knapsack Sprayer	54.00	2.837
15 - 20 cm	No Weed Control	50.33	2.837
15 - 20 cm	Weed Wiper	48.67	2.837
20 - 25 cm	Cutlass	50.67	2.837
20 - 25 cm	Hoe	54.00	2.837
20 - 25 cm	Knapsack Sprayer	50.67	2.837
20 - 25 cm	No Weed Control	50.67	2.837
20 - 25 cm	Weed Wiper	54.67	2.837

5th August, 2009.

General Linear Model: Porosity, % versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Porosity, %, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	104.43	104.43	52.22	4.18	0.023
Ploughing Depth	3	280.40	280.40	93.47	7.49	0.000
Weed Control	4	86.67	86.67	21.67	1.74	0.162
Ploughing Depth*Weed Control	12	67.60	67.60	5.63	0.45	0.930
Error	38	474.23	474.23	12.48		
Total	59	1013.33				

S = 3.53268   R-Sq = 53.20%   R-Sq(adj) = 27.34%

Unusual Observations for Porosity, %

Obs	Porosity, %	Fit	SE Fit	Residual	St Resid	
28	53.0000	46.8833	2.1391	6.1167	2.18	R
38	44.0000	52.2167	2.1391	-8.2167	-2.92	R
43	56.0000	50.0333	2.1391	5.9667	2.12	R
48	44.0000	50.0333	2.1391	-6.0333	-2.15	R

R denotes an observation with a large standardized residual.

Least Squares Means for Porosity, %

Ploughing De	Mean	SE Mean
0 cm	47.07	0.9121
10 - 15 cm	47.33	0.9121
15 - 20 cm	46.87	0.9121
20 - 25 cm	52.07	0.9121

```
Weed Control
Cutlass                         49.42   1.0198
Hoe                             47.25   1.0198
Knapsack Sprayer                47.08   1.0198
No Weed Control                 50.08   1.0198
Weed Wiper                      47.83   1.0198
Ploughing De*Weed Control
0 cm         Cutlass            48.67   2.0396
0 cm         Hoe                44.67   2.0396
0 cm         Knapsack Sprayer   45.33   2.0396
0 cm         No Weed Control    50.67   2.0396
0 cm         Weed Wiper         46.00   2.0396
10 - 15 cm   Cutlass            48.67   2.0396
10 - 15 cm   Hoe                48.00   2.0396
10 - 15 cm   Knapsack Sprayer   46.33   2.0396
10 - 15 cm   No Weed Control    48.67   2.0396
10 - 15 cm   Weed Wiper         45.00   2.0396
15 - 20 cm   Cutlass            46.33   2.0396
15 - 20 cm   Hoe                46.67   2.0396
15 - 20 cm   Knapsack Sprayer   45.67   2.0396
15 - 20 cm   No Weed Control    48.00   2.0396
15 - 20 cm   Weed Wiper         47.67   2.0396
20 - 25 cm   Cutlass            54.00   2.0396
20 - 25 cm   Hoe                49.67   2.0396
20 - 25 cm   Knapsack Sprayer   51.00   2.0396
20 - 25 cm   No Weed Control    53.00   2.0396
20 - 25 cm   Weed Wiper         52.67   2.0396
```

5th October, 2009.

General Linear Model: Porosity, % versus Block, Ploughing Depth, ...

```
Factor            Type   Levels  Values
Block             fixed       3  1, 2, 3
Ploughing Depth   fixed       4  0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control      fixed       5  Cutlass, Hoe, Knapsack Sprayer, No Weed
                                 Control, Weed Wiper

Analysis of Variance for Porosity, %, using Adjusted SS for Tests
Source                        DF   Seq SS   Adj SS  Adj MS     F      P
Block                          2   290.63   290.63  145.32  3.23  0.051
Ploughing Depth                3    87.07    87.07   29.02  0.65  0.590
Weed Control                   4    64.73    64.73   16.18  0.36  0.835
Ploughing Depth*Weed Control  12   137.27   137.27   11.44  0.25  0.993
Error                         38  1708.03  1708.03   44.95
Total                         59  2287.73

S = 6.70435   R-Sq = 25.34%   R-Sq(adj) = 0.00%

Unusual Observations for Porosity, %
Obs  Porosity, %      Fit  SE Fit  Residual  St Resid
 46      42.0000  52.8667  4.0597  -10.8667     -2.04 R

R denotes an observation with a large standardized residual.

Least Squares Means for Porosity, %
Ploughing De                     Mean  SE Mean
0 cm                            50.20    1.731
10 - 15 cm                      50.07    1.731
15 - 20 cm                      47.87    1.731
20 - 25 cm                      47.60    1.731
Weed Control
Cutlass                         50.08    1.935
Hoe                             47.42    1.935
Knapsack Sprayer                48.00    1.935
No Weed Control                 49.42    1.935
Weed Wiper                      49.75    1.935

Ploughing De*Weed Control
```

0 cm	Cutlass	54.33	3.871
0 cm	Hoe	47.33	3.871
0 cm	Knapsack Sprayer	46.67	3.871
0 cm	No Weed Control	52.33	3.871
0 cm	Weed Wiper	50.33	3.871
10 - 15 cm	Cutlass	51.67	3.871
10 - 15 cm	Hoe	49.00	3.871
10 - 15 cm	Knapsack Sprayer	50.00	3.871
10 - 15 cm	No Weed Control	50.00	3.871
10 - 15 cm	Weed Wiper	49.67	3.871
15 - 20 cm	Cutlass	46.33	3.871
15 - 20 cm	Hoe	48.00	3.871
15 - 20 cm	Knapsack Sprayer	46.33	3.871
15 - 20 cm	No Weed Control	49.00	3.871
15 - 20 cm	Weed Wiper	49.67	3.871
20 - 25 cm	Cutlass	48.00	3.871
20 - 25 cm	Hoe	45.33	3.871
20 - 25 cm	Knapsack Sprayer	49.00	3.871
20 - 25 cm	No Weed Control	46.33	3.871
20 - 25 cm	Weed Wiper	49.33	3.871

SOIL AIR CONTENT ANOVA (0 – 15cm)

20th May, 2009.

General Linear Model: Air Content (%) versus Block, Pl Depth (cm), ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Pl Depth (cm)	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Air Content (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	270.01	270.01	135.01	3.05	0.059
Pl Depth (cm)	3	10.24	10.24	3.41	0.08	0.972
Weed Control	4	77.77	77.77	19.44	0.44	0.779
Pl Depth (cm)*Weed Control	12	119.99	119.99	10.00	0.23	0.996
Error	38	1679.80	1679.80	44.21		
Total	59	2157.82				

S = 6.64871   R-Sq = 22.15%   R-Sq(adj) = 0.00%

Unusual Observations for Air Content (%)

Obs	Air Content (%)	Fit	SE Fit	Residual	St Resid
29	24.7000	37.1010	4.0260	-12.4010	-2.34 R
49	48.1900	34.9590	4.0260	13.2310	2.50 R

R denotes an observation with a large standardized residual.

Least Squares Means for Air Content (%)

Pl Depth (cm		Mean	SE Mean
0 cm		34.89	1.717
10 - 15 cm		34.82	1.717
15 - 20 cm		35.01	1.717
20 - 25 cm		35.85	1.717
Weed Control			
Cutlass		34.61	1.919
Hoe		37.23	1.919
Knapsack Sprayer		33.80	1.919
No Weed Control		35.13	1.919
Weed Wiper		34.96	1.919
Pl Depth (cm*Weed Control			
0 cm	Cutlass	32.96	3.839
0 cm	Hoe	36.54	3.839
0 cm	Knapsack Sprayer	36.04	3.839

0 cm	No Weed Control	34.07	3.839
0 cm	Weed Wiper	34.86	3.839
10 - 15 cm	Cutlass	33.87	3.839
10 - 15 cm	Hoe	34.67	3.839
10 - 15 cm	Knapsack Sprayer	34.43	3.839
10 - 15 cm	No Weed Control	36.49	3.839
10 - 15 cm	Weed Wiper	34.66	3.839
15 - 20 cm	Cutlass	33.51	3.839
15 - 20 cm	Hoe	39.44	3.839
15 - 20 cm	Knapsack Sprayer	32.72	3.839
15 - 20 cm	No Weed Control	34.45	3.839
15 - 20 cm	Weed Wiper	34.93	3.839
20 - 25 cm	Cutlass	38.10	3.839
20 - 25 cm	Hoe	38.26	3.839
20 - 25 cm	Knapsack Sprayer	31.99	3.839
20 - 25 cm	No Weed Control	35.51	3.839
20 - 25 cm	Weed Wiper	35.40	3.839

5th August, 2009.

General Linear Model: Air Content versus Block, Ploughing De, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth (cm)	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Air Content (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	29.28	29.28	14.64	0.66	0.523
Ploughing Depth (cm)	3	196.02	196.02	65.34	2.94	0.045
Weed Control	4	193.72	193.72	48.43	2.18	0.090
Ploughing Depth (cm)*Weed Control	12	268.82	268.82	22.40	1.01	0.460
Error	38	843.63	843.63	22.20		
Total	59	1531.47				

S = 4.71176   R-Sq = 44.91%   R-Sq(adj) = 14.47%

Unusual Observations for Air Content (%)

Obs	Air Content (%)	Fit	SE Fit	Residual	St Resid
20	39.6500	31.7965	2.8531	7.8535	2.09 R
27	46.9500	34.3635	2.8531	12.5865	3.36 R
48	25.3400	33.2733	2.8531	-7.9333	-2.12 R

R denotes an observation with a large standardized residual.

Least Squares Means for Air Content (%)

Ploughing Depth		Mean	SE Mean
0 cm		30.91	1.217
10 - 15 cm		29.30	1.217
15 - 20 cm		30.50	1.217
20 - 25 cm		34.18	1.217
Weed Control			
Cutlass		32.19	1.360
Hoe		32.14	1.360
Knapsack Sprayer		28.56	1.360
No Weed Control		33.47	1.360
Weed Wiper		29.73	1.360
Ploughing De*Weed Control			
0 cm	Cutlass	29.60	2.720
0 cm	Hoe	29.76	2.720
0 cm	Knapsack Sprayer	30.13	2.720
0 cm	No Weed Control	36.25	2.720
0 cm	Weed Wiper	28.80	2.720
10 - 15 cm	Cutlass	32.38	2.720
10 - 15 cm	Hoe	35.18	2.720
10 - 15 cm	Knapsack Sprayer	25.65	2.720
10 - 15 cm	No Weed Control	28.90	2.720

10 - 15 cm	Weed Wiper	24.36	2.720
15 - 20 cm	Cutlass	31.99	2.720
15 - 20 cm	Hoe	30.61	2.720
15 - 20 cm	Knapsack Sprayer	26.59	2.720
15 - 20 cm	No Weed Control	31.65	2.720
15 - 20 cm	Weed Wiper	31.65	2.720
20 - 25 cm	Cutlass	34.79	2.720
20 - 25 cm	Hoe	33.02	2.720
20 - 25 cm	Knapsack Sprayer	31.87	2.720
20 - 25 cm	No Weed Control	37.10	2.720
20 - 25 cm	Weed Wiper	34.11	2.720

5th October, 2009.

General Linear Model: Air Content (%) versus Block, Ploughing Depth, ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Air Content (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	113.75	113.75	56.87	1.17	0.320
Ploughing Depth	3	189.58	189.58	63.19	1.31	0.287
Weed Control	4	193.28	193.28	48.32	1.00	0.420
Ploughing Depth*Weed Control	12	195.82	195.82	16.32	0.34	0.977
Error	38	1839.34	1839.34	48.40		
Total	59	2531.76				

S = 6.95727   R-Sq = 27.35%   R-Sq(adj) = 0.00%

Unusual Observations for Air Content (%)

Obs	Air Content (%)	Fit	SE Fit	Residual	St Resid
48	22.7800	34.7857	4.2128	-12.0057	-2.17 R

R denotes an observation with a large standardized residual.

Least Squares Means for Air Content (%)

Ploughing De		Mean	SE Mean
0 cm		32.48	1.796
10 - 15 cm		33.44	1.796
15 - 20 cm		30.01	1.796
20 - 25 cm		29.06	1.796
Weed Control			
Cutlass		32.04	2.008
Hoe		29.95	2.008
Knapsack Sprayer		28.75	2.008
No Weed Control		33.98	2.008
Weed Wiper		31.51	2.008
Ploughing De*Weed Control			
0 cm	Cutlass	34.76	4.017
0 cm	Hoe	28.22	4.017
0 cm	Knapsack Sprayer	29.10	4.017
0 cm	No Weed Control	37.28	4.017
0 cm	Weed Wiper	33.06	4.017
10 - 15 cm	Cutlass	34.33	4.017
10 - 15 cm	Hoe	35.94	4.017
10 - 15 cm	Knapsack Sprayer	30.98	4.017
10 - 15 cm	No Weed Control	33.42	4.017
10 - 15 cm	Weed Wiper	32.52	4.017
15 - 20 cm	Cutlass	30.71	4.017
15 - 20 cm	Hoe	28.58	4.017
15 - 20 cm	Knapsack Sprayer	24.94	4.017
15 - 20 cm	No Weed Control	34.24	4.017

15 - 20 cm	Weed Wiper	31.59	4.017
20 - 25 cm	Cutlass	28.37	4.017
20 - 25 cm	Hoe	27.08	4.017
20 - 25 cm	Knapsack Sprayer	29.97	4.017
20 - 25 cm	No Weed Control	30.99	4.017
20 - 25 cm	Weed Wiper	28.89	4.017

SOIL AIR CONTENT ANOVA (15 – 30cm)

20th May, 2009.

General Linear Model: Air Content (%) versus Block, Pl Depth (cm), ...

Factor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Pl Depth (cm)	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Air Content (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	216.36	216.36	108.18	2.24	0.121
Pl Depth (cm)	3	75.34	75.34	25.11	0.52	0.672
Weed Control	4	13.48	13.48	3.37	0.07	0.991
Pl Depth (cm)*Weed Control	12	159.46	159.46	13.29	0.27	0.990
Error	38	1837.60	1837.60	48.36		
Total	59	2302.24				

S = 6.95399   R-Sq = 20.18%   R-Sq(adj) = 0.00%

Unusual Observations for Air Content (%)

Obs	Air Content (%)	Fit	SE Fit	Residual	St Resid	
24	49.6900	37.3087	4.2108	12.3813	2.24	R
25	50.1300	38.7753	4.2108	11.3547	2.05	R

R denotes an observation with a large standardized residual.

Least Squares Means for Air Content (%)

Pl Depth (cm		Mean	SE Mean
0 cm		36.17	1.796
10 - 15 cm		36.31	1.796
15 - 20 cm		38.23	1.796
20 - 25 cm		38.68	1.796
Weed Control			
Cutlass		36.85	2.007
Hoe		37.68	2.007
Knapsack Sprayer		37.80	2.007
No Weed Control		36.70	2.007
Weed Wiper		37.71	2.007
Pl Depth (cm*Weed Control			
0 cm	Cutlass	36.08	4.015
0 cm	Hoe	35.06	4.015
0 cm	Knapsack Sprayer	36.58	4.015
0 cm	No Weed Control	38.03	4.015
0 cm	Weed Wiper	35.11	4.015
10 - 15 cm	Cutlass	37.86	4.015
10 - 15 cm	Hoe	35.92	4.015
10 - 15 cm	Knapsack Sprayer	36.20	4.015
10 - 15 cm	No Weed Control	33.37	4.015
10 - 15 cm	Weed Wiper	38.21	4.015
15 - 20 cm	Cutlass	38.24	4.015
15 - 20 cm	Hoe	38.75	4.015
15 - 20 cm	Knapsack Sprayer	39.36	4.015
15 - 20 cm	No Weed Control	38.80	4.015
15 - 20 cm	Weed Wiper	35.99	4.015
20 - 25 cm	Cutlass	35.21	4.015
20 - 25 cm	Hoe	41.00	4.015
20 - 25 cm	Knapsack Sprayer	39.08	4.015
20 - 25 cm	No Weed Control	36.60	4.015

20 - 25 cm	Weed Wiper	41.52	4.015

5th August, 2009.

General Linear Model: Air Content versus Block, Ploughing De, ...

actor	Type	Levels	Values
Block	fixed	3	1, 2, 3
Ploughing Depth (cm)	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Air Content (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	154.98	154.98	77.49	2.83	0.071
Ploughing Depth (cm)	3	232.31	232.31	77.44	2.83	0.051
Weed Control	4	503.60	503.60	125.90	4.60	0.004
Ploughing Depth (cm)*Weed Control	12	226.58	226.58	18.88	0.69	0.750
Error	38	1039.98	1039.98	27.37		
Total	59	2157.44				

S = 5.23143   R-Sq = 51.80%   R-Sq(adj) = 25.16%

Unusual Observations for Air Content (%)

Obs	Air Content (%)	Fit	SE Fit	Residual	St Resid	
20	41.7300	30.4467	3.1678	11.2833	2.71	R
28	43.1800	32.6998	3.1678	10.4802	2.52	R
43	42.3600	30.8802	3.1678	11.4798	2.76	R
60	17.3700	28.3402	3.1678	-10.9702	-2.63	R

R denotes an observation with a large standardized residual.

Least Squares Means for Air Content (%)

Ploughing Depth		Mean	SE Mean
0 cm		30.40	1.351
10 - 15 cm		31.27	1.351
15 - 20 cm		31.12	1.351
20 - 25 cm		35.41	1.351
Weed Control			
Cutlass		33.88	1.510
Hoe		31.58	1.510
Knapsack Sprayer		27.46	1.510
No Weed Control		36.13	1.510
Weed Wiper		31.21	1.510
Ploughing De*Weed Control			
0 cm	Cutlass	30.97	3.020
0 cm	Hoe	27.51	3.020
0 cm	Knapsack Sprayer	27.62	3.020
0 cm	No Weed Control	36.70	3.020
0 cm	Weed Wiper	29.21	3.020
10 - 15 cm	Cutlass	34.62	3.020
10 - 15 cm	Hoe	34.39	3.020
10 - 15 cm	Knapsack Sprayer	26.32	3.020
10 - 15 cm	No Weed Control	34.66	3.020
10 - 15 cm	Weed Wiper	26.39	3.020
15 - 20 cm	Cutlass	30.74	3.020
15 - 20 cm	Hoe	30.44	3.020
15 - 20 cm	Knapsack Sprayer	27.49	3.020
15 - 20 cm	No Weed Control	34.86	3.020
15 - 20 cm	Weed Wiper	32.09	3.020
20 - 25 cm	Cutlass	39.18	3.020
20 - 25 cm	Hoe	33.99	3.020
20 - 25 cm	Knapsack Sprayer	28.43	3.020
20 - 25 cm	No Weed Control	38.31	3.020
20 - 25 cm	Weed Wiper	37.15	3.020

5th October, 2009.

General Linear Model: Air Content (%) versus Block, Ploughing Depth, ...

Factor   Type   Levels   Values

Block	fixed	3	1, 2, 3
Ploughing Depth	fixed	4	0 cm, 10 - 15 cm, 15 - 20 cm, 20 - 25 cm
Weed Control	fixed	5	Cutlass, Hoe, Knapsack Sprayer, No Weed Control, Weed Wiper

Analysis of Variance for Air Content (%), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Block	2	427.99	427.99	213.99	2.71	0.079
Ploughing Depth	3	502.79	502.79	167.60	2.12	0.113
Weed Control	4	193.10	193.10	48.27	0.61	0.657
Ploughing Depth*Weed Control	12	273.57	273.57	22.80	0.29	0.988
Error	38	2997.81	2997.81	78.89		
Total	59	4395.25				

S = 8.88199   R-Sq = 31.79%   R-Sq(adj) = 0.00%

Unusual Observations for Air Content (%)

Obs	Air Content (%)	Fit	SE Fit	Residual	St Resid
48	25.0400	39.5225	5.3783	-14.4825	-2.05 R

R denotes an observation with a large standardized residual.

Least Squares Means for Air Content (%)

Ploughing De	Mean	SE Mean
0 cm	33.14	2.293
10 - 15 cm	33.92	2.293
15 - 20 cm	28.96	2.293
20 - 25 cm	26.93	2.293

Weed Control	Mean	SE Mean
Cutlass	32.47	2.564
Hoe	28.57	2.564
Knapsack Sprayer	28.65	2.564
No Weed Control	32.65	2.564
Weed Wiper	31.36	2.564

Ploughing De*Weed Control		Mean	SE Mean
0 cm	Cutlass	38.54	5.128
0 cm	Hoe	29.11	5.128
0 cm	Knapsack Sprayer	28.74	5.128
0 cm	No Weed Control	36.60	5.128
0 cm	Weed Wiper	32.68	5.128
10 - 15 cm	Cutlass	35.78	5.128
10 - 15 cm	Hoe	32.93	5.128
10 - 15 cm	Knapsack Sprayer	33.75	5.128
10 - 15 cm	No Weed Control	35.28	5.128
10 - 15 cm	Weed Wiper	31.88	5.128
15 - 20 cm	Cutlass	27.60	5.128
15 - 20 cm	Hoe	27.72	5.128
15 - 20 cm	Knapsack Sprayer	25.11	5.128
15 - 20 cm	No Weed Control	33.90	5.128
15 - 20 cm	Weed Wiper	30.48	5.128
20 - 25 cm	Cutlass	27.94	5.128
20 - 25 cm	Hoe	24.51	5.128
20 - 25 cm	Knapsack Sprayer	27.01	5.128
20 - 25 cm	No Weed Control	24.83	5.128
20 - 25 cm	Weed Wiper	30.39	5.128