# A PRELIMINARY EVALUATION OF CHLORO-NICOTINYL APHICIDES AS PLANTING-HOLE TREATMENTS AGAINST THE TOBACCO APHID *Myzus persicae nicotianae.*

**By**

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**A dissertation submitted in partial fulfilment of the requirements for the Bachelor of Science Honours in Biological Sciences**

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**June 2013**

**Abstract**

A field trial was done to examine the efficacy of chloro-nicotinyl aphicides applied as soil applications, and to determine the optimum rate for fipronil, acetamiprid and calypso for control of the tobacco aphid *Myzus persicae*. The tobacco variety KRK26 was used in this experiment. The plants were initially exposed to natural infestation by the tobacco aphid. At eight weeks after planting (WAP) the plants were artificially infested with cultured aphids after an assessment of natural infestation was done. Assessments were done at weekly intervals up to 11WAP. The aphicides thiamethaxom, imidacloprid 350 SC and fipronil at a rate of 500 $ml.Ha^{-1}$ exhibited efficacies against the aphids comparable to the two standard aphicides actara and confidor. The aphicide thiamethaxom had the highest residual activity as it was able to effectively control aphids even up to the last assessment week (11 WAP), followed by fipronil and then imidacloprid. This indicates that these three aphicides could potentially be used as soil applications to effectively control *M. persicae*. In contrast, the rest of the treatments showed little or no efficacy against the tobacco aphid. The suitable application rates for the efficacious chemicals were125 $ml.100^{-1}$ for thiamethaxom, 170 $ml.100L^{-1}$ for imidacloprid 350 SC and 500 $ml.Ha^{-1}$ for fipronil.

**ACKNOWLEDGEMENTS**

I would like to express my sincere gratitude to my lecturers, friends and family whose contributions were integral to the compilation of this thesis. I would like to acknowledge with sincere gratitude great assistance and productive comments by my supervisor Dr Muteveri when we worked on this thesis. For the same assistance, I thank my co-supervisors Miss R Masukwedza, Dr Dimbi and Mr Chinheya whose productive contribution was integral to the success of my project. Once again I say thanks, without you my project would not have been a success. I would also like to express my profound and sincere gratitude to the whole Kutsaga Research Board for the technical and material support relevant and assistance rendered to me in conducting this project. I also thank all the members of the Biological Sciences students because in many ways, what l learnt during my four years in the department contributed to ideas that shaped this dissertation. Special thanks also goes to Simbarashe Mudzamiri for his continual support that helped me successfully achieve this project. I also do extend my deepest gratitude to my Lord Jesus Christ for his grace and protection throughout my studies.

Finally I owe special thanks to my family for their support, love and motivation throughout my studies.

**Dedication**

Dedicated to Simbarashe Mudzamiri and the whole Matanhire family, my mom and dad, my brother John, all my sisters and my son Takunda for giving me support during the time I needed it most.

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## CHAPTER 1: INTRODUCTION

### 1.1 Background

Tobacco (*Nicotiana tabacum* L.) is a high value crop whose production dates back to the colonial era in Zimbabwe (Mazarura, 2004). It is the backbone of commercial agriculture in Zimbabwe since it is a high value crop contributing significantly to the gross domestic profit of the economy and to export revenue (Mutsakani, 2004).

Tobacco is grown for its leaf where nicotine the major economic product of tobacco is extracted, (Mazarura, 2004). In Zimbabwe, it is grown as a summer crop and it requires a 7 to 9-month growing season in order to produce a full crop (Masuka *et al.,* 1998). Zimbabwe is one of the major tobacco exporters in the world. In 1996-1998, average annual exports of tobacco were 127 000 tonnes. The average export revenue during that time was US$7 875 million and tobacco has been the largest single export crop in recent decades. The crop normally accounts for more than 50% of agricultural exports, 30% of total exports and nearly 10% Gross Domestic profit (GDP). Subsequently, the crop became the major foreign currency earner. Zimbabwe had established an international reputation of producing a high quality crop and high nicotine content that compete favourably on the world market. However, tobacco production in Zimbabwe has of the late markedly declined as a result of damage by pest and diseases (Nvakazeya, 2011).

Just like any other crop tobacco is under the threat of pests and diseases. It is continuously affected by harmful organisms, which negatively affect it. Among these organisms are bacteria and fungi which cause diseases such as bacterial or Granville wilt, frogeye, root rot and soreshin (Masuka *et al*., 2010). Viral diseases include bushy-top, potato virus Y and the tobacco mosaic. Tobacco is plagued by a number of insect pests, which damage the plant directly by feeding on the plant tissue and also indirectly by being viral disease vectors. Major insect pests include cutworms (*Agrotis* species); budworms (*Helicoverpa armigera*); white flies (*Bemisia tabaci*) and the aphids (*Myzus nicotianae*). These are potentially the greatest threat to the tobacco industry in Zimbabwe as well as the tobacco farming countries (Masuka *et al.,* 2010).

M*yzus persicae nicotianae* is a pest of great economic importance as it transmits several devastating viral disease and is widely distributed affecting over 40 host plants including tobacco. Aphids are small soft-bodied sap sucking insects found in groups underneath leaves**.** They are of two forms the green and the red morphs and they may be winged or wingless. The wingless aphids are important for clonal development and reproduction. They are usually yellowish in colour and they make colonies at the underneath the leaf. The winged morphs enable aphids to leave their hosts and migrate to new hosts to form new colonies (Margaritopoulos *et al.*, 2000).

**1.2 Problem Statement**

Aphid colonies can cause physical degradation of the leaf by mechanical damage caused by their stylets as they suck the sap from the host plant (Blackman, 1987). Physical damage is also caused by the formation of honeydew, which is a substrate of fungi responsible for producing sooty-moulds. However, these effects are not nearly as important as the virus diseases they transmit, which include the Potato Virus Y, Alfalfa Mosaic Virus and the most serious being the Bushy-top Virus (Wu *et al.*, 2004). The result of these aphid induced diseases on tobacco is reduced weight and shrivelling of the leaves, decreased growth, and finally death of the plant. This causes large yield losses as tobacco is priced by virtue of leaf quality. Aphids transmitting viruses in the seedbed can easily infect all the seedlings because infection is not immediately apparent and symptoms may appear weeks after seedlings have been transplanted. Tobacco viruses are carried by migrating aphids, which may travel as far as 1300km by wind and storm.

Tobacco aphid infestations usually begin when winged adults fly into fields and deposit young ones on plants. This happens about 4-6 weeks after transplanting. High aphid populations can lead to reduced yield by 5-25%. Thus these insects must be managed properly to prevent serious economic damage to the crop. Miyata (1983), states that the green peach aphid has a well-documented resistance to a variety of insect classes. Over the past few years, organophosphates, pyrethroids and carbamates have been used to control tobacco aphids worldwide. However these insecticides are no longer because the aphids exhibit high levels of resistance to them. For example, resistance was first reported in the United States to carbamate, organophosphate and pyrethroids insecticides (Georghiou, 1963;Sudderuddin, 1973).

The first resistance mechanism reported in *M.persicae* was amplification of genes, E4 and FE4 that code for the production of the E4 and FE4 carboexylesterases that degrade or sequester organophosphate, carbamates and pyrethroids insecticides (IRAC, 2000). Evolution of resistance is supported by the existence of several tobacco aphid colour morphs and because of the ability of the aphids to interbreed under laboratory conditions (Devonshire and Sawicki, 1979).

**1.3 Justification**

The current study was carried out as part of a major initiative aimed at finding a solution to the pesticide resistance problem exhibited by tobacco aphids. This present research was initiated to explore the efficacy chloro-nicotinyl-based aphicides in the control and management of the tobacco aphid *Myzus persicae*. Chloro-nicotinyls have a potential to control tobacco aphids as: (1) they have a different mode of action, and (2) they have an excellent systemic and translaminar property. In addition the research seeks to explore the rate of application at which each pesticide is effective against the tobacco aphid.

## 1.4 Objectives

The main objective of this study was to determine the efficacy of chloro-nicotinyl-based aphicides applied as planting-hole treatments. The specific objectives were to:(1) Determine if significant aphid control can be obtained through the application of chloro-nicotinyl-based aphicides as planting-hole treatments, and (2) Determine the optimum rate of application for fipronil, acetamiprid and calypso being tested for the first time as soil applications.

## CHAPTER 2: LITERATURE REVIEW

### 2.1 Botany of Tobacco

Tobacco is an agricultural product processed from the leaves of plants in the genus *Nicotiana* of the *Solanaceae* family (nightshade family) (Mazarura, 2004). It can be consumed, used as a pesticide and in the form nicotine tartrate used in some medicines. It is mostly used in cigars and cigarettes, snuff, pipe and chewing tobacco. The chief commercial product is *N tabacum* and it is believed native to tropical America, like most *Nicotiana* plants. The alkaloid nicotine is the most characteristic constituent of tobacco and is responsible for its addictive nature (Tobacco facts, 2008). The usage of tobacco is an activity that is practiced by some 1.1 billion people, and up to 1/3 of the adult population. There are more than 70 species of tobacco, of which 45 are native to the Americas. The two cultivated species, common tobacco and wild tobacco, are annuals i.e. they live only one growing season. Common tobacco is 1 to 3 m tall and has a thick, woody stem with few side branches. One plant typically produces 10 to 20 broad harvestable leaves that branch alternately from the central stalk. The leaf size depends on the strain. The narrow, trumpet-shaped flowers are dark pink to almost white. Wild tobacco is about 0.6 m tall and has a stem that is more slender and less woody than common tobacco. The leaves have a short stalk that attaches to the stem (Tucker 1982).The flowers are pale yellow with five separate lobes. There are three different types grown in Zimbabwe, which are Flue-cured, Burley and Oriental tobacco, flue-cured tobacco being the most commonly grown in Zimbabwe (Davies *et al.*, 1999).

#### 2.1.1 The tobacco aphid

The tobacco aphid is known as *Myzus persicae nicotianae*. It is the tobacco-feeding form of the Green Peach Aphid (GPA) (Blackman, 1987).

Tobacco aphids on tobacco Tobacco aphid

Figure 1: The tobacco aphid.

CREDITS: Flue-Cured Tobacco Field Guide a diagnostic guide to field problems (Masuka, A., Dimbi, S. and Sigobodhla, T. E).

**2.1.2 Taxonomy of the tobacco aphid**

*Myzus nicotianae (Sulzer*) is classified as follows

**2.1.2.1 Pest Status**

**2.1.2.2 Taxonomic Classification**

Kingdom: Animalia

Phylum: Arthopoda

Class: Insecta

Order: Hemiptera

Family: Aphididae

Tribe: Aphidini

Sub-tribe: Macrosiphina

Genus: *Myzus*

Species: *nicotianae*

### 2.1.3 Description of aphids

The *Myzus persicae* belongs to the family Aphididae, within the order Homoptera, the plant sucking bugs. They are an extremely successful group, which occurs throughout the world with the greatest number of species in the temperate regions (Dixon, 1998). Unlike the Potato aphid, several generations are born a year and their fecundity has been described as fantastic by many authors. Aphids are small (1-10 mm), soft-bodied, plant sucking insects, the mouthparts of which are modified to form piercing and sucking tubes. According to Blackman (1987), about 4,000 species of aphid have been described with the greatest number occurring in the temperate regions 1 out of every 4 plant species is infested. Even though relatively small in number compared to grasshoppers, geometrid moths and weevils, aphids are quite diverse. This diversity is expressed as polyphenism (the occurrence within a species of different forms or morphs) as well as speciation. Takada (1981) says that aphids exhibit two morphs, the green and the red morphs and they may be winged or wingless. Several or all generations comprise parthenogentic females, which do not require fertilization and are viviparous (give birth to live young). Some species show cyclical parthenogenesis, i.e. the life cycle alternates between an 'anholocyclic' one (devoid of sexual reproduction) and a 'holocyclic' one (with sexual reproduction). Eggs of parthenogentic females commence development immediately after ovulation. Embryonic development of her young begins before the mother's birth, in the body of the grandmother. Aphids have an incomplete metamorphosis, their being no pupal stage built a series of molts in which the nymph gradually becomes a mature adult (Shaw, 1967).

### 2.1.3.1 The apteral and alatae forms of the tobacco aphid

There are only two body forms: the wingless (apteral) and the winged (alate). Wingless individuals are formed from the nymphs deposited by the winged individuals that initiate a colony. In favourable, spacious conditions, they, in turn, produce more wingless individuals and so rapidly build up the colony numbers. Wingless aphids can spread virus infections distances of only a few metres. Miyazaki (1987), states that the wingless aphids are important for clonal development, reproduction and are usually yellowish in colour and they make colonies at the underneath the leaf. When the colony starts to become crowded or the nutritional suitability of the plant deteriorates, winged individuals start to be produced. Under poor conditions for growth, this may occur within two weeks of colony foundation. Ideally, aphid infestations should be controlled before effects occur (Blackman, 1987).

The apterous aphids measure about 1.7-2.0 mm in length (Capinera, 2001) and lateral green stripes may be present. The cornicles are moderately long, unevenly swollen along their length, and match the body colour. The appendages are pale with siphunculi and cauda relatively shorter than those of the winged form. They have converging antennal tubercles.

The alate aphids have a black head and thorax, and a yellowish–green abdomen with a large dark patch dorsally, measuring 1.8-2.1mm in length (Capinera, 2001).The winged morphs enable aphids to leave their hosts and migrate to new hosts to form new colonies. These seemingly attempt to colonize nearly all plants available, depositing a few young before they take flight again. This highly dispersive nature contributes significantly to the effectiveness as vectors of plant viruses. It only takes a few seconds for a winged red aphid to transmit the diseases and thus no insecticide can act fast enough to prevent transmission of viruses. The nymphs resemble the apterous adult.

### 2.1.3.2 Life cycle the tobacco aphid

The life cycle varies considerably, depending on climate. Development can be rapid, often 10-12 days for a complete generation and with over 20 annual generations reported in mild climates. The young are born fully formed and able to feed immediately. They grow rapidly, molting (shedding their skin) 4 times before they mature, often reaching maturity within a week. Since fertilization is not required, ova can start developing within an aphid as soon as or even before it is born (Cottrell, 1994). In tropical regions, *M. persicae* species appears to make little use of its primary host, the peach, *Prunus persicae*, and completes its life cycle mainly on the secondary hosts of which tobacco is the principal one. This anholocyclic development involves only the parthenogenetic, viviparous, alate and apterous forms (Tamaki, 1982). Where suitable host plants cannot persist during the winter season, the aphid overwinters in the egg stage on *Prunus* species. In the spring, soon after the plant breaks dormancy and begins to grow, the eggs hatch and the nymphs feed on flowers, young foliage, and stems. After several generations, winged dispersants from overwintering *Prunus* species deposit nymphs on summer hosts. In cold climates, adults return to *Prunus* spp. in the autumn, where mating occurs, and eggs are deposited. All generations except the autumn generation are parthenogenetic (non-sexual) (Throne, 1985).

**Adult-**

The small adult green peach aphid is light to dark green or pink, with red eyes. Three dark lines run down its back. Wings may or may not be present. The tobacco aphid is similar and can be either red or green.

**Egg-**

Eggs measure about 0.6 mm long and 0.3 mm wide, and are elliptical in shape. They initially are yellow or green, but soon turn black and shiny for the green peach aphid.. Mortality in the egg stage sometimes is quite high. Eggs measure about 0.6 mm long and 0.3 mm wide, and are elliptical in shape. They initially are yellow or green, but soon turn black. Mortality in the egg stage sometimes is quite high (Cottrell, 1994)

**Nymph-**

The wingless nymph resembles the larger adult. Nymphs initially are greenish, but soon turn yellowish, greatly resembling viviparous adults. In studies done using viviparous aphids, 4-5 instars have been reported, with a nymph duration of 8-9 days (Throne, 1985).

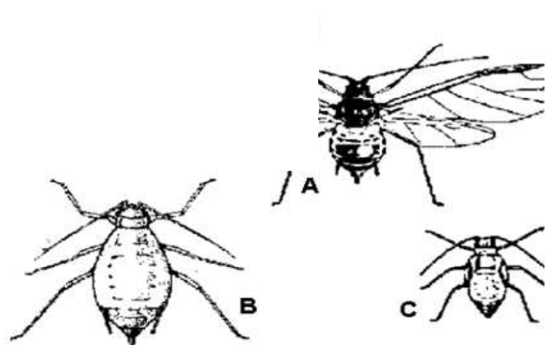


Figure 2: Tobacco aphid forms.

A. Winged adult. B. Wingless adult. C. Nymph with wing buds. (Blackman, 1987).

#### 2.1.3.3 Aphid nutrition and feeding behaviour.

Most aphids are ultimately phloem feeders hence feed by sucking plant juices (sap) resulting in reduced leaf quality. Most, if not all, aphids' species feed on phloem sap. This sap is rich in sugars and relatively poor in amino acids, especially those that are essential for growth. Thus, in order to fuel their very high rates of growth, aphids need to process large quantities of food and use the nitrogen it contains effectively. Higher nitrogen levels are found in the phloem sap of plants that are growing, flowering or senescent, because of the translocation of nutrients that will be still in process during those periods. The mouthparts have evolved and they are specialized for the ingestion of a liquid diet. The parts that penetrate into plant tissues are two pairs of shorter chitinous bristles with pointed tips the stylets (Dixon, 1998). An outer pair the mandibular stylets, greatly enlarged within the head, pass towards the buccal cavity and become considerably attenuated and closely sheath of the outer sides of the inner maxillary stylets. The *Myzus persicae* was found to require an average less than 21µ under 1min, from less 21 to over 100µ in 1-10 min, the percentage of penetration over 100µ deep increasing with 20-30minutes in tobacco plants. In piercing plant tissue, the mandibles move alternately to channel a path for themselves and for the salivary and food canals formed between paired maxillae. Feeding by aphids' results in reduced vigor of infected plants, curling of leaves, stunting of growth, and death of branches in severe cases (Dixon, 1998).

#### 2.1.3.4 Host selection and location

Aphid's acceptance or rejection of a host plant is a complex process governed by visual, tactile and chemical cues. From contact with leaf surface and probes lasting from a few seconds to several minutes in the epidermis, an aphid receives stimulation whether to continue probing.

Excitatory gustatory stimuli tend to increase the frequency and duration of probes (Blackman, 1987). If the host provides appropriate cues, the aphid settles and probes deeper, the stylets eventually reaching the phloem. Aphids may be autoecious (host-specific) or heteroecious (host-alternatng). About 10% are heteroecious, they spend autumn, winter and spring on a primary host (a woody plant, perennial plants with hard stems and barks), and the summer on a secondary host plant, usually a succulent annual weeds or cultivated plants such as tobacco and cabbage . However most aphids are autoecios, living on one or a few species of a particular genus of plants. Plants are colonized primarily by alates (i.e. winged forms)**.** When within the layer of relatively still air around vegetation (called the "boundary layer"), aphids can control their landing on plants and respond to either olfactory or visual cues (especially yellow colour) or both. Both highly nutritious young and senescent foliage tends to be yellower than the nutritionally poorer mature leaves.

Host plant selection and acceptance by aphids has been divided into three categories which are olfactory attraction which is the sensory physiology of host selection by aphids, visual attraction which is the visual response of an aphid and host appraisal. Visual attraction is grouped into two categories, photo taxis-directed colour reaction (Moericke, 1950) and optomotor reaction-alightments supposedly being provoked by objects suddenly appearing in the path of the flying aphid.

After settling, a potential host is recognized by the structure and chemistry of its surface and internal tissues. Some aphids (example *Brevicoryne brassicae* and *Aphis fabae*) are mainly associated with new growth whereas other species (example *Myzus persicae*) show different preferences depending on the host. On crucifers and potatoes, *M. persicae* mainly colonises ageing and senescing leaves. On tobacco, *M. persicae nicotianae* feeds on young leaves – hence pinching out the top leaves ('topping') significantly reduces aphid infestation (Moericke, 1950).

### 2.1.3.5 Alternation of host plants

Dispersal to an alternate host plant generally requires production of winged progeny that disperse to secondary hosts of the same or different species. For example in the bird cherry oat aphid *Rhopalisiphum padi* and English grain aphid *Sitobian avanae (Fabricus),* the proportion of offsprings developing wings increases with crowding, and more so if both mothers and offspring experience crowding. Other cues that trigger or influence production of winged progeny can include deteriorating host quality or intrinsic maternal control mechanism. Trees or shrubs can be excellent hosts early in the growing season but most are poor or unsuitable hosts in summer (Tamaki, 1982).

### 2.1.4 Life history

In October the female lay eggs usually on the stems of trees or shrubs. The eggs are black, with thick shells and can withstand extremes of temperature. It is in the egg form only that aphids pass the winter. In March the eggs hatch out into wingless female nymphs which are similar to the adults, with three pairs of legs, compound eyes and antennae. There is no larval or pupal stage comparable to those of the butterfly, but with successive moults and continuous growth the nymphs become mature females (Horsfall, 1924). No males are hatched at all, the female nymphs feed on the shoots and leaves of the tree on which they hatch, at the time when the buds are sprouting .after a series of ecdyses (moults), they become mature and give birth to daughter aphids without any fertilisation. This kind of reproduction is called parthenogenesis. The daughters are not produced from eggs but are born alive as nymphs though they are surrounded at first by a transparent capsule like an egg membrane. The daughters quickly and themselves have offsprings by parthenogenesis. Some of these develop wings which grow larger at each ecdysis. These winged daughter fly off to any herbaceous plant such as a rose tree or been plant. The winged forms have two pairs of wings of which the hind pair is quite small. Both pairs are transparent with few veins. The aphids are not strong fliers but tend to be carried by chance air currents rather than make direct flights. When the winged generation reach the new food plant, they give birth to wingless daughters parthenogenetically (Horsfall 1924). In warm weather these may mature in 8 to 10 days and begin to reproduce in the same way by bearing winged daughters which fly off and infest new plants. This process of parthenogenesis goes on all through the summer months, winged or wingless generations more or less alternating. Enormous numbers of aphids are produced in this way though a great many are killed by birds, ladybirds and their larvae, laceworms larvae and cold weather.

## 2.2 EFFECTS OF APHIDS ON TOBACCO

Tobacco aphids infestations generally begin when winged adults fly into fields and deposit young ones on plants. This happens about 4-6 weeks after transplanting. Aphids damage tobacco either directly or indirectly. Directly by sucking plant juices resulting in weight loss, shrivelling of leaves and reduced quality (Chari and Nagarajan, 2000).

### 2.2.1 Aphid indirect damage

The ability of *M. persicae* to disseminate numerous viruses (example bushy-top virus in tobacco) makes it one of the most economically important aphid species. Severe aphid infestation may occur causing transmission of viral diseases such as bushy-top, sooty mould, Potato Virus Y

(PVY), as well mosaic viruses like alfalfa mosaic virus, cucumber mosaic virus and tobacco mosaic virus (Wu *et al.*, 2004).

#### 2.2.1.1 Tobacco bronzing disease

Tobacco bronzing first appeared in the Tengwe area in the 1974-75 season. Investigations at the Kutsaga indicate that it may be a complex disease, since two types of virus particle appear to be present (Marco, 1993). Presumably, both are transmitted together by the aphid vector. One of these particles is Potato Virus Y, the other has not been named or characterized other than morphologically (Cottrell, 1994).

#### 2.2.1.2 Potato Virus Y

The Potato Virus Y, like other viruses, can occur in a number of strains that differ in the degree of virulence that they display in different host plants. The ordinary strain of PVY causes a severe disease in potatoes called Leaf Drop Streak. In tobacco it is a relatively mild, non-distorting disease referred to as PVY (Masuka *et al.,* 2010).

Figure 3: Potato Virus Y on tobacco.

CREDITS: Flue-Cured Tobacco Field Guide a diagnostic guide to field

Problems. (Masuka, A., Dimbi, S. and Sigobodhla, T. E).

**Symptoms**

Various symptoms on tobacco include vein-clearing, vein-banding, vein yellowing, chlorotic rings, a rugose mosaic at the leaf apices and margins, as well as necrosis of the veins only and leaf tissue between the veins and white or brown necrotic spot (Masuka *et al.*, 2010).

White and necrotic spots may be confused with those of weather fleck**.** In contrast, the necrotic strain of PVY causes only a mild disease in potatoes and a severe one, known as Tobacco Venal Necrosis in tobacco.

**2.2.1.3 Tobacco venal necrosis disease**

The disease was first noted in tobacco in Zimbabwe in 1961. Subsequent investigations strongly suggested that it had been imported in seed potatoes from Holland (Cottrell, 1994). Since there is no dead season for potatoes, aphids can carry the virus from a winter potato crop to a tobacco crop that is present at the same time and from this tobacco back to summer and early winter potato plantings. In areas where both crops are grown on a commercial scale, a situation is created in which the virus can survive from season to season and, with the passage of time, increase the geographical area that it affects.

**2.2.1.4 Cucumber mosaic virus (CMV)**

Infection by this virus causes a mosaic pattern of light and dark green areas that can be confused with that caused by TMV.

Figure 4: Cucumber Mosaic Virus (CMV) Disease on tobacco.

CREDITS: Flue-Cured Tobacco Field Guide a diagnostic guide to field problems, (Masuka, A., Dimbi, S. and Sigobodhla, T. E).

**2.2.1.5 Alfalfa Mosaic Disease**

Alfalfa Mosaic was definitely recorded in tobacco in Zimbabwe for the first time in the Mutorashanga and Harare South areas in the 1993-94 seasons. It is well known in other tobacco growing areas of the world and has a wide host range that includes leguminous as well as solanaceous plants. It has been shown to be seed borne in peppers. A pepper strain that produces a more severe necrosis of tobacco than does the ordinary strain, has been recorded in Ontario, Canada (Kennedy, Day and Eastop, 1962).

Figure: 5 Alfalfa Mosaic Disease on tobacco

CREDITS: Flue-Cured Tobacco Field Guide a diagnostic guide to field problems, (Masuka, A., Dimbi, S. and Sigobodhla, T. E).

**Symptoms**

Symptoms include bright yellow or off-white patches among green areas, broad rings and a mosaic pattern on young leaves.

### 2.2.1.6 Rosette and Bushy-top Diseases

Tobacco Bushy Top Disease (TBTD) is caused by Tobacco Bushy Top Virus (TBTV) and the two viruses that cause the Tobacco Rosette Disease complex (TRDC), that is, the Tobacco Mottle Virus (TMV) with a diameter of 8-9nm and Tobacco Vein Distorting Virus (TVDV) with a diameter of 2-13nm (Wickens, 1938). The Tobacco Rosette Disease Complex was first reported and described by Wickens in 1938. The disease had been noted in a late crop in the Mvurwi District of Zimbabwe. According to Gates (1962), the first report of TBTD in Zimbabwe was made in 1958. The disease was later reported in other Southern African countries including South Africa, Zambia and Malawi (Wickens, 1938). The outbreak in China in 1999 was the first major outbreak outside Southern Africa (SA). Other than in SA and China, TBTD has also been reported in Pakistan. In Zimbabwe, it became economically important after 2000 following the advent of the agrarian reform, and possibly due to changes in the population dynamics of the aphids that have been noted. It has been found that the disease incidence is higher in the late planted crops (late November and December in the Southern Hemisphere) than in those early planted earlier (October and early November). Severity of the disease also depends on the plant growth stage when infection occurs. Symptoms are more severe if infection occurs in the first 3-5 weeks after transplanting and almost negligible when plants infected in the mature stage(Mo, Qin, Tan, Wu, and Chen, 2002).

**Symptoms**

The symptoms mottling of the leaves and vein distortion. Backward and downward curling of leaves. Plants attain a bushy appearance because of the excessive growth of auxiliary buds. Flowering and seed production is also affected, with little or no seed being set.

Figure 6: A Bushy-Top affected tobacco crop.

CREDITS: Flue-Cured Tobacco Field Guide a diagnostic guide to field problems, (Masuka, A., Dimbi, S. and Sigobodhla).

**2.2.1.7 Sooty mould**

When feeding, aphid colonies secrete copious amounts of honey-dew (a sugary secretion) on which a sooty mould develops. They excrete a sugary liquid, or honeydew. The honeydew not only clogs the pores of the leaves, but also encourages the growth of black, sooty mold, which can prevent light from reaching the photosynthetic tissue of the plant. Aphids weaken the plant by draining its fluids. This may cause severe distortion of growth, and are common means of transmitting plant viruses (Masuka *et al.*, 2010).

Figure 7: Sooty mould on a tobacco plant.

CREDITS: Flue-Cured Tobacco Field Guide a diagnostic guide to field problems,(Masuka, A., Dimbi, S. and Sigobodhla, T. E).

**Symptoms**

Leaves and fruits are tainted and results in significant quality losses. The leaves become thinner, black and stuck together.

Overally the resultant of these aphid induced effects is reduced weight of the plant, decreased growth shrivelling of leaves and finally death of the plant. Gradually these tobacco induced viruses lead to huge losses on the plant since tobacco is priced by virtue of l

**2.3 CONTROL METHODS OF THE TOBACCO APHID**

One way of controlling aphids is through the integrated pest management technique (IPM) which combines all the effective, economical and environmentally sound pest control strategies into a single flexible approach to managing pests. It encompasses practices such as biological control, cultural, legislative as well as chemical control (Wei *et al.,* 2005)

### 2.3.1 Biological control

Biological control is the conscious use of living beneficial organisms, called natural enemies for the control of pests (Kostal *et al.*, 2001). In this case aphid control is brought about through natural enemies such as predators like ladybird which eat the aphids or aphid parasitoids that parasitizes the aphids by either laying their eggs like in the case of wasp, lacewings, syrphid flies, damsel bugs, wasps, parasitic fungi and entomopathogenic nematodes (EPNs) tend to regulate green peach aphid populations outdoors. Rain, wind, and mud also help check aphid populations outside (Mackauer, 1968).

In greenhouse crops, where environmental conditions and predator, parasitoid and pathogen densities can be manipulated, biological suppression is more effective and consistent. One parasitoid that has been used widely in the greenhouses as biological control of aphids is *Aphidius gifuensis* (Wei *et al.* 2005). Indeed, there has been considerable success using parasitoids, the entomopathogenic fungus *Verticillium lecanii*, and the predatory midge *Aphidoletes aphidimyza* (Diptera: Cecidomyiidae) for greenhouse-grown vegetables, especially in Europe Despite the beneficial nature of these biotic agents, very low aphid densities can effectively transmit virus diseases. In crops susceptible to aphid-borne virus disease, natural enemies alone are probably destined to be relatively ineffective in preventing damage. Also the augmentative release of natural enemies involves costs that are frequently higher than pesticide applications, limited release seldom translate to economical control of pests' populations and many environmental factors can limit the effectiveness of biological control (Steenwyk, 2004).

In the field, biological control agents may be differentially affected by the cropping system. For example, Tamaki *et al.* (1982) found that the wasp *Diaeretiella rapae* (Hymenoptera: Braconidae) was more effective in broccoli, whereas lady beetle (Coleoptera: Coccinellidae) and big-eyed bug (Hemiptera: Lygaeidae) predators were more effective on radish.

### 2.3.2 Cultural Practices

Aphicidal tactics can be supplemented by a few simple cultural practices aimed at minimizing the spread of aphid-borne virus diseases. Cultural control involves farming practices that can reduce pest populations by making their environment less favourable. These farming practices include crop rotation, sanitation, strip cropping, and insectary planting to mention a few. Installation of trapping networks intended to monitor aphid flight in a particular area is another control measure. In general, the principle that different solanaceous crops should be separated as far as possible from each other in space and time should be observed. This particularly applies to tobacco seedbeds. Solanaceous weeds should be removed from within tobacco lands as well as from the areas surrounding them and should also be controlled in winter-irrigated crops (Blackman, 1987).

Isolated virus-infected plants amounting to less than 4 to 5% of the stand should be removed to prevent them acting as virus reservoirs for the further spread of viruses. If this is done at an early growth stage, compensatory growth by adjacent plants will tend to reduce any yield losses to less than would be expected on the basis of actual loss of stand (Cottrell, 1994). However this method of pest control poses some problems in that he traps may not be monitored and expertise is required to accurately identify the true *Myzus persicae.* Radcliffe *et al.* (2002) also stated that regardless of the monitoring methodology used a delay always occurs in processing the samples, summarizing the data and alerting the farmers on the findings.

### 2.3.3 Legislative controls

Undoubtedly the most important of all the tactics used to control aphid-borne virus diseases are the regulations governing the earliest dates for sowing seedbeds and for planting out as well as those governing the final dates for seedbed and stalk destruction. Legislated plant destruction and sowing dates in tobacco – to minimise carryover of aphid-transmitted virus diseases (bushy-top and PVY) these are: May 15$^{th}$ – latest date of destruction of tobacco plants in the lands. June 1$^{st}$ – earliest tobacco seedbed sowing date ( Masuka *et al.*, 2010). This may be considered the absolute minimum period, workable only if meticulous stalk destruction and re-growth prevention is actually practiced in the lands. Blair(1994), says that considerably longer period would be preferable and growers should ensure that stalk destruction is carried out as soon as possible after reaping is completed instead of waiting for the final date. Nothing is more deleterious to the suppression of aphid-borne virus diseases than large areas of stand-over tobacco or of regrowth that persist into the dead period. Viruses, even if they did not show symptoms during the growing period might well have infected the plants, before reaping was completed. They will then serve not only as aphid hosts but also as virus reservoirs promoting the survival of both kinds of organisms through the winter as well as their dissemination to naturally occurring hosts.

### 2.3.4 Chemical control

Chemical control measures are the most reliable means currently available to control thetobacco aphids (Sannino *et al.*, 1998).It involves the use of chemical insecticides to control pests. The use of insecticides based on different chemistries and with varying mode of action is a fundamental measure to the issue of pest management. Aphicides used for controlling tobacco aphids are drawn from different chemical groups such as avermectin (example, abamectin), pyretheroids (deltamethrin), organophosphates (chlorpyrifos), carbamates (cabaryl) as well chloro-nicotinyls (actara, imidacloprid, thiamethaxom, acetamiprid for instance). Despite the numerous options potentially available, many producers are dependent on insecticides for suppression of tobacco aphid abundance. Chemical insecticides can be applied both systemically ( at planting) where the aphicide is allowed to move up within the system of the plant for example nicotinoids like thiamethoxam and imidacloprid and as contact aphicides where the aphicide is applied as a spray for instance dimethoate, acephate, methamidophos, thiacloprid, acetamiprid (a nicotinoid), monocrotophos and many others (Palumbo and Kerns, 1994). Systemic insecticide applications are especially popular at planting time, most of which provide long-lasting protection against aphid population build up during the critical and susceptible early stages of plant growth (Powell, 1980) and some of which provide protection for 3 months.

For some time organophosphates, pyretheroids and carbamates have been used to control aphids but are currently ineffective because the tobacco aphids exhibit high levels of resistance to these insecticides and this resistance is conferred by one of two inter-specifically identical, amplified esterase genes(Kranthi *et al.*, 2001). The first resistance mechanism reported in *M.persicae* was amplification of genes, E4 and FE4, which code for production of the E4 and FE45 carboexysterases that degrade or sequester organophosphates, carbamates and pyretheroids insecticides. This resistance was attributed to the constant use of the same insecticide for control. Therefore it was recommended to use aphicides with different modes of action to counteract aphicidal resistance by aphids (Mutsakani, 2004).

Chloro-nicotinyls are a new class of chemicals formerly known as neonicotinoids, nitro-quadines and chloro-nicotines. They include thiamethaxom, acetamiprid, thiacloprid (calypso), fipronil, imidacloprid, confidor and many others. Chloro-nocotinyls appear to be the most effective insecticide because they have a broad insecticidal spectrum, excellent systemic and translaminar properties as well as a high residual activity (NASS, 2000). They are transported throughout the plant in a transpirational stream and provide a certain degree of residual activity. The products available in chloro-nicotinyls vary in their water solubility which affects how rapidly the active ingredient is taken up by the plant. Chloro-nicotinyls have a different mode of action compared to organophosphates, carbamates and pyrethroids. Pyrethroids are synthetic compounds whose structure and mode of action are similar to pyrethrins. Like many other insecticides pyrethroids are neurotoxic and work by incapacitating the creature preventing it from feeding on the crop. However pyrethroids are not effective as planting-hole treatments hence are generally applied as foliar sprays. There is need to constantly spray the plants with pyrethroids since the residue is short-lived. Also pyrethroids can be very expensive and also they are more prone to resistance by aphids (Duan *et al*., 2001)

They kill target pests in the same manner as the natural product nicotine by acting on the central nervous system, causing irreversible blockage of the post-synaptic nicotinergic acetylcholine receptors. They also disrupt nerve transmission in insects, causing firing of nerves. This results in rapid pulses from the steady influx of sodium leading to hyperexcitation, convulsions, paralysis and finally death of the insect. A general characteristic of chloro-nicotinyls is that they are highly effective against phloem feeding or sucking insects such as aphids (Wu *et al.*, 2004).

Chloro-nicotinyls can be absorbed both systemically and as foliar curative applications, but have along effective value when absorbed systemically because the residue is short-lived in the environment (Duan *et al.*, 2001). As a foliar spray imidacloprid has a relatively slow mode of action on aphids that may reduce its effectiveness as a foliar insecticide for controlling viral disease caused by immigrating viruliferous aphids. Nevertheless foliar sprays can be effective in reducing resident aphid populations but they tend to be much less effective against immigrating aphids because the persistence of aphicidal residues is often shorter than the interval between spray applications. Movement of sprayer through the crop may promote interplant movement and aphid flight actively increasing virus spread (NASS, 2000).

Calypso 480 SC insecticide is a suspension concentrate formulation that contains the active ingredient thiacloprid at 480 $g.L^{-1}$. Calypso 480 SC is intended for use in controlling aphids on a variety of plants including tobacco and it is closely related to imidacloprid. The use of high doses increases the likelihood that potentially significant toxic effects would be exhibited in the pest being controlled. Acetamiprid is a second-generation chloro-nicotinyl insecticide with contact and systemic activity through foliar applications. It is excellent on sucking pests like aphids and whitefly, but it has very marginal activity when applied to soil. Thiamethaxom is a second-generation chloro-nicotinyl that is effective against aphids, whitefly as well as thrips and it is said to be more mobile in the soil than imidacloprid (Matthew, 1992).

Link *et al.* (2000) evaluated the efficacy of chemical control of *M. persicae* and concluded that the insecticide imidacloprid was efficient in the control of this pest. In experiment conducted by Syed *et al.* (2005)to test the efficacy of different insecticides against aphid *Myzus persicae* on tobacco crop, found out that among the different pesticides tested, confidor and actara gave the lowest *M. persicae* population. Sannio (1997) found confidor with high performance against *M. persicae* in an experiment in Olivola. Ramaprasad *et al.* (1998) conducted experiment in Andra Pradesh, India, to evaluate the performance of confidor and other insecticides for controlling *M. persicae.* They found that confidor effectively controlled the pest population throughout the year.

Takahashi *et al.* (1992), say that, acetamiprid, a new broad spectrum systemic insecticide, belonging to the family of chloro-nicotinyls (neonicotinoids) shows high activity against Hemiptera, especially aphids, and also Thysanoptera and Lepidoptera.

The Pesticide Action Network of Asia and Pacific (PAN AP) (2011), stated that imidacloprid has a moderate to very high persistence in soil under aerobic conditions (half life of 40-997 days), in one US field, concentrations did not decrease after 1 year. This persistence in soil in the absence of light makes imidacloprid suitable for seed treatment and incorporated soil application since it allows continual availability for uptake by the plant roots (Mullins, 1993). Thus, imidacloprid can persist in soil depending on soil type, pH, use of organic fertilizers, as well as presence or absence of ground cover (Sarkar *et al.*, 2001). Acetamiprid has been seen to have a half-life of only 8 days in soil. For thiamethaxom, the persistence in soil is very high, with a half-life of 38-280days such that residues can be detected in succeeding crops. Thiacloprid (calypso) has a low persistence in soil with a half life of 2-27days (PAN AP, 2011). Persistence in soil allows for continual availability for uptake by plant roots (Mullins, 1993).

# CHAPTER 3: MATERIALS AND METHODS

## 3.1Study Area

The research was conducted as a field trial at Tobacco Research Board Lands, Land 3 during the 2011/12 cropping season. The station is located 15km east of Harare (17`55``S 31`08``E) with an elevation of 1479 m above sea level. The research station falls in the Agro-ecological Region II, which receives up to 800 mm of rainfall (Nyamapfene, 1991). The area has light, well drained, sandy soils of granite origin and resembles those found in most tobacco growing areas in Zimbabwe. The soils are very low in clay content and have low water holding capacity. They are slightly acidic with a pH of 5.2.

## 3.2 Experimental Design

The design used was a randomised block design (RBD) with two blocks each with fifteen treatments. Each treatment consisted of one row of 32 plants of the KRK26 cultivar treated with a particular aphicide. Inter-row spacing was 1.2 m and intra-row plant spacing was 56 cm. Two border rows were put in place around the experiment.

## 3.3 Procedure

### 3.3.1 Aphid cultures

The Aphid culture was collected from tobacco cultivar KRK26 grown at the Kutsaga Research Station and was reared and maintained on potted tobacco plants (KRK26) in the screencages until it was ready for se.

### 3.3.2 Seedling preparation

Seedlings were grown at the entomology seedbed sites. The beds varied in length and their widths were wide enough to fit three trays and four trays side by side, thus 1.05 m for three trays and 1.40 m for four trays. The bed was lined with 250 µm gauge black plastic. The plastic was laid over the top of the wall of the bed and, at least partially down the outside of the wall. The bed was then filled with water. The plastic was flattened against the bottom and sides of the pond to remove wrinkles and ay irregularities.

The medium was be prepared by mixing pine-bark with water in the ratio 2:1. The medium was then poured into the float trays evenly. Depressions were made at the centre of each cell on the float tray using a dibble board. Raw seed cultivar KRK26 was sown into the depressions in each cell. Floatfert was added to each seedbed at 7, 21, 35 days after sowing. Ammonium nitrate was applied at 100 $mg.NL^{-1}$ of water six weeks after sowing.

**Table 1 List of treatments**

| Treatment number | Name of treatment | Rate of application |
|---|---|---|
| **1.** | Untreated control | Nil |
| **2.** | Actara 25 WG(std) | 12 g.100L$^{-1}$ |
| **3.** | Confidor 200 SL (std) | 220 ml.100L$^{-1}$ |
| **4.** | Thiamethaxom | 125 ml.100L$^{-1}$ |
| **5.** | Imidacloprid 350 SL | 170 ml.100L$^{-1}$ |
| **6.** | Imidacloprid 350 SC | 170 ml.100L$^{-1}$ |
| **7.** | Fipronil (Citchem) | 500 ml.Ha$^{-1}$ |
| **8.** | Fipronil | 750 ml.Ha$^{-1}$ |
| **9.** | Fipronil | 1000 ml.Ha$^{-1}$ |
| **10.** | Calypso(thiacloprid) | 30 ml.100L$^{-1}$ |
| **11.** | Calypso | 60 ml.100L$^{-1}$ |
| **12.** | Calypso | 120 ml.100L$^{-1}$ |
| **13.** | Acetamiprid | 15 g.100L$^{-1}$ |
| **14.** | Acetamiprid | 30 g.100L$^{-1}$ |
| **15.** | Acetamiprid | 45 g.100L$^{-1}$ |

### 3.3.3 Transplanting

Seedlings were drenched two days before pulling with 2 L.m$^{-2}$ of Baytan (*Trichoderma)* plus triademenol 15% WP at a rate of 165 g 100L$^{-1}$ water. During transplanting a 20 cm hole was filled with about 2 Litres of water. One seedling was planted in the hole and the surrounding soil was used to cover the plant. Chlorpyrifos 48% EC (50 ml.25L$^{-1}$ of water) was applied around the base of the plant (cup number 30). Aphicidal treatments were also applied at planting and all cultural practices (weeding, fertilizing and topping) for tobacco were standard.

Figure 8: transplanting of tobacco seedlings in the fields

### 3.4 Determining the efficacy of chloro-nicotinyls aphicides

Prior to the experiment seedlings were raised in the seedbeds from July /August and transplanted in the fields on 22 November 2011. Appropriate dilutions of each chemical were made. Aphicides were applied manually after planting around the base of the plant using a 30ml cup.

Figure 9: Planting-hole aphicide application.

**3.4.1 To determine the optimum rate of application for each chemical.**

This experiment seeks to evaluate the rate of a chemical at which significant aphid control can be obtained. To get this each of the aphicides fipronil, acetamiprid and calypso was divided into three application rates and each rate had to be replicated twice (once in each block).

**3.4.2Aphid infestation**

The plants were initially exposed to natural infestation. Infestations began at 8WAP because of weather conditions, rain came later in the season. Each plant in a row was artificially infested using ten aphids through the help of a soft-bristled penbrush, but prior to this infestation a score for possible natural infestation was done. Assessments of aphid scores in each plot was done at weekly intervals up to 11WAP using a score range of 0-4 where 0=0 aphids observed, 1=1-10 aphids recorded, 2=11-100 aphids recorded, 3 = 101- 1000aphids recorded, 4 = 1001and more than.

### 3.5 Statistical analysis

Data collected was subjected to blocked analysis of variance (ANOVA) with two blocks corresponding to the two plots used and 15 treatments corresponding to different aphicides at different rates as shown in Table 1 above. Since ANOVA yielded a significant difference among treatments, the Tukey post hoc multiple comparison test as implemented in SPSS was used to locate differences. All the statistical analyses were implemented in SPSS version 16.

## CHAPTER 4: RESULTS

### 4.1 Aphid score assessments at 8 weeks after planting (WAP)

At 8 WAP there were significant differences in aphid control amongst the treatments ($p < 0.05$) (Appendix 2). Generally it can be observed that thiamethaxom, imidacloprid 350SC and fipronil at its low rate had significantly lower aphid scores, of 0.06, 0.03 and 0.18 respectively than the rest of the aphicides (Fig. 10). However the rest of the treatments had significantly high aphid scores. Calypso at 120 ml.100L$^{-1}$ and acetamiprid at 45 g.100L$^{-1}$ had the highest aphid scores of 1.46 and 1.47 respectively (Fig. 10). Multiple comparison tests showed significant differences within the chemicals insecticides being noted between the following : thiamethaxom 125 g.100L$^{-1}$, imidacloprid 350SC at 170 g.100L$^{-1}$ and fipronil 500ml.Ha$^{-1}$ were comparable to the standard aphicide actara 125g.100L$^{-1}$ ($p > 0.05$) (appendix 2) and even had lower aphid scores than the standard aphicide confidor 220ml.100L$^{-1}$. These three aphicides differed signicantly from the untreated control and the rest of the aphicides ($p < 0.05$) (appendix 2). However there were no significant differences between blocks ($p>0.05$) (Appendix 2).

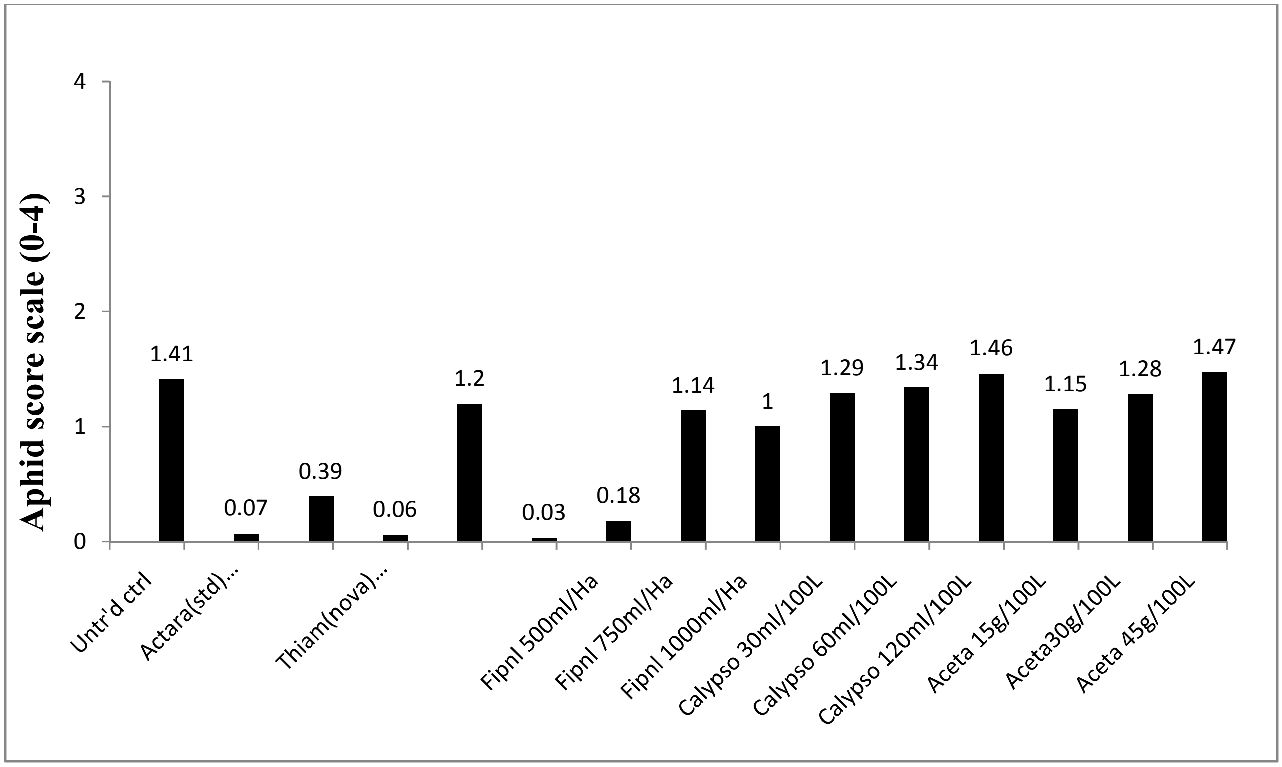


Figure 10: Mean aphid scores at 8 weeks after planting (WAP) per treatment.

### 4.2 Aphid score assessments at 9 weeks after planting

Similarly at 9WAP significant differences were observed amongst the treatments ($p < 0.05$) (Appendix 3). Thiamethaxom, imidacloprid 350 SC and fipronil at its low rate had the lowest aphid scores of 0.24, 0.53 and 0.73 respectively. The rest of the treatments had high aphid scores. In this case we now have imidacloprid 200 SL at 220 g.100$^{-1}$ and fipronil at 1000 ml.100L$^{-1}$ attaining the highest aphid scores of 1.8 and 1.87 respectively (Fig. 11). After multiple comparison test between treatments, significant differences were noted among the following aphicides: the same aphicides thiamethaxom, imidacloprid 200 SL and fipronil 500 ml.Ha$^{-1}$ were significantly comparable to the standard aphicides actara and confidor ($p > 0.05$) (Appendix 3) but differed significantly from the rest of the treatments and the untreated control ($p < 0.05$) (Appendix 3). Significant differences were also noted between blocks ($p < 0.05$) (Appendix 3).

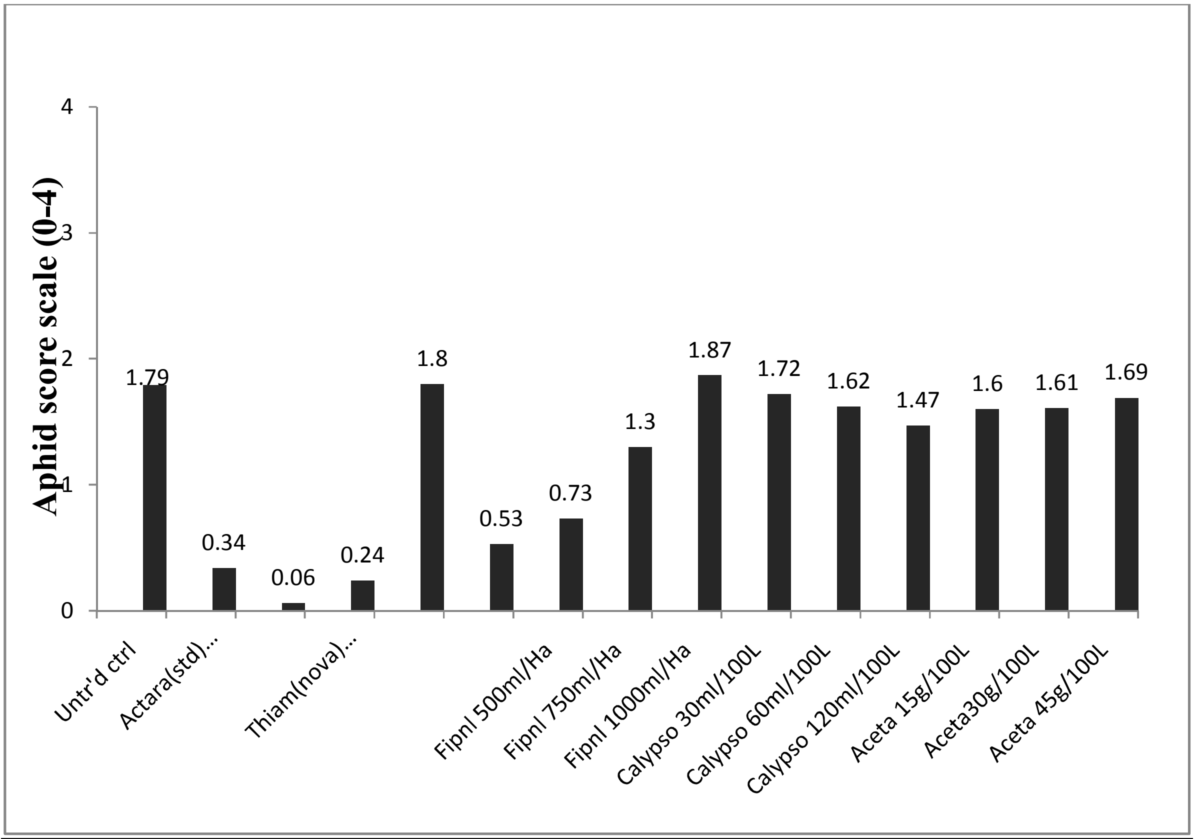


Figure 11: Mean aphid scores at 9 weeks after planting (WAP) per treatment.

**4.3 Aphid score assessments at 10 weeks after planting.**

The trends shown are still the same with 8 and 9 WAP, there are significant differences amongst the treatments at 10 WAP ($p < 0.05$) (Appendix 4). The same treatments thiamethaxom, fipronil lower rate and imidacloprid 200 SL are still attaining significantly lower aphid scores while the rest of the treatments have significantly high aphid scores (Fig. 12). Multiple comparison tests among the treatments showed that there were significant differences among the following aphicides: fipronil 500 ml.$Ha^{-1}$ imidacloprid 200 SL and thiamethaxom differed significantly from the rest of the aphicidal treatments and the untreated control ($p < 0.05$) (Appendix 4) but were significantly comparable to the two standard aphicides actara and confidor ($p > 0.05$) (Appendix 4). No significant differences were noted between the two blocks ($p > 0.05$) (Appendix 4).

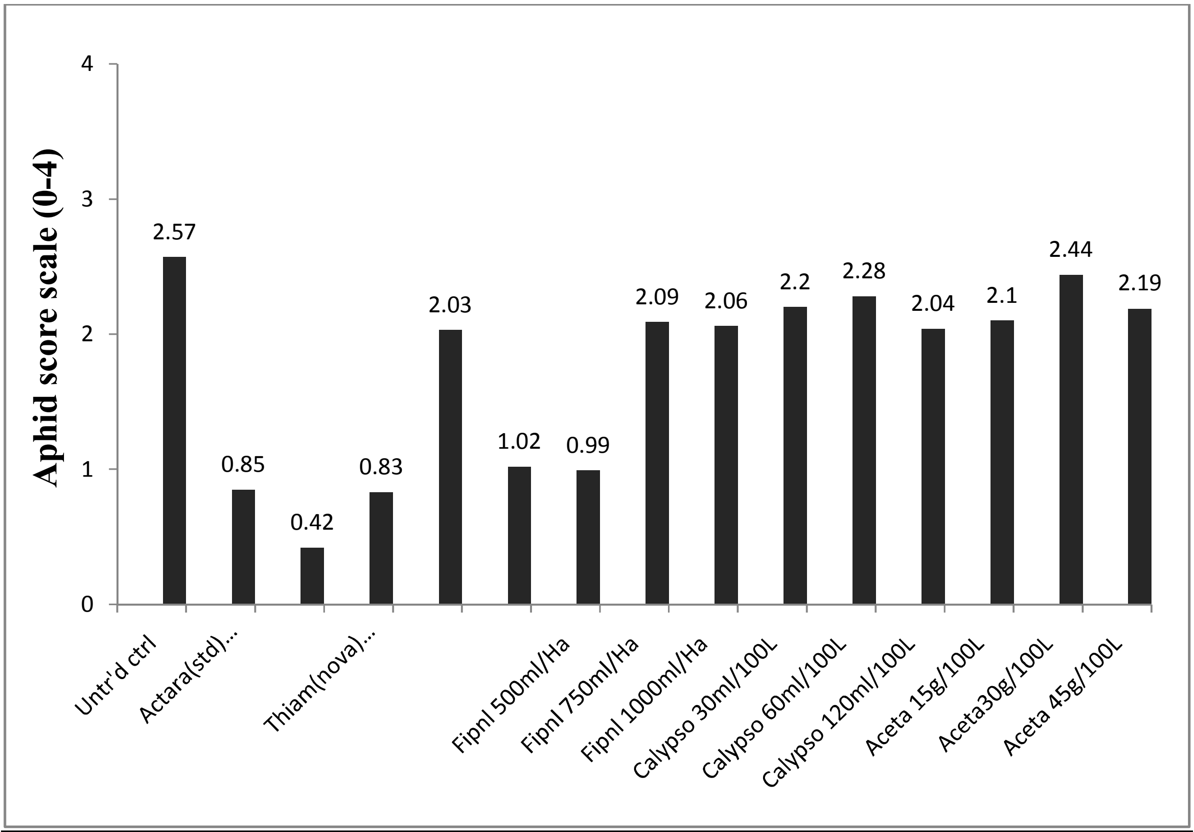


Figure 12: Mean aphid scores at 10 weeks after planting per treatment

**4.4 Aphid score assessments at 11 weeks after planting.**

At 11WAP again significant differences existed among the treatments ($p < 0.05$) (Appendix 5). Lower aphid scores have been observed in thiamethaxom with 0.5, imidacloprid 350 SC and fipronil at 500 ml.$Ha^{-1}$ have 1.21 and 1.14, respectively (Fig 12). Similarly the rest of the treatments show significantly high aphid scores. Multiple comparison test indicated that differences existed between thiamethaxom, fipronil 500 ml.Ha$^{-1}$ and imidacloprid 350SC with the untreated control and the rest of the aphicidal treatments ($p < 0.05$) (appendix 5) but did not differ significantly from the two standard aphicides ($p > 0.05$) (appendix 5). No significant differences were observed between the two blocks ($p > 0.05$) (Appendix 5).

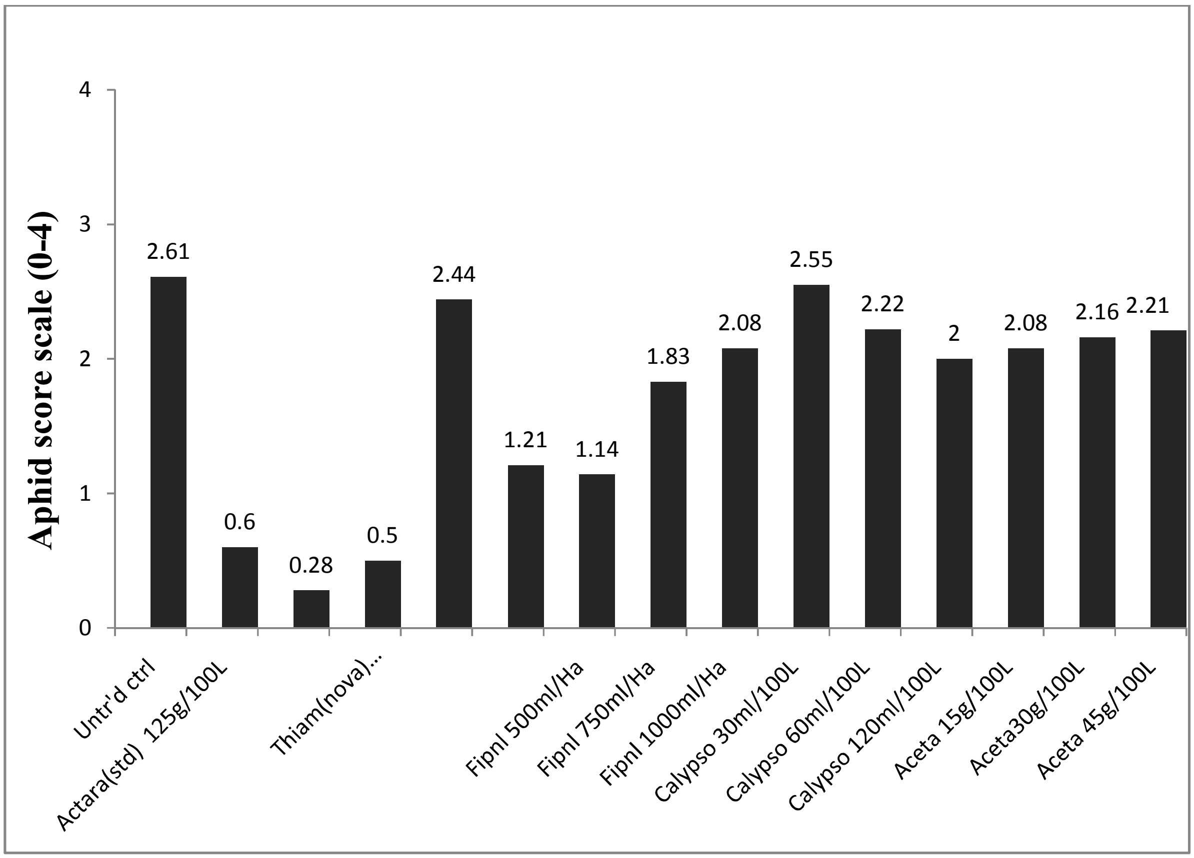


Figure 13: Mean aphid scores at 11weeks after planting.

# CHAPTER 5: DISCUSSION

## 5.1 Efficacy and residual effect of the aphicides used.

The evaluation of new compounds with good efficacy and novel biochemical modes of action has become a necessity for the continued management of tobacco aphids following their resistance to pyrethroids, organophosphate and carbamates.

Considering the results from 8 to 11 weeks after planting, there were three new aphicides that were at least as efficacious as the traditional ones actara and confidor. ANOVA recovered significant differences in aphid scores among the aphicidal treatments ($p < 0.05$) (Appendix 2-5). Tukey multiple comparisons showed that the aphicides thiamethaxom (125 ml.100 $L^{-1}$), imidacloprid 350SC (170 ml.100 $L^{-1}$) and fipronil (500ml.$Ha^{-1}$) were more efficacious than the others as they gave the least aphid scores (Figs. 10 – 13).

In all the four assessment weeks thiamethaxom, imidacloprid 350SC and fipronil at the rate of 500 ml.$Ha^{-1}$ showed highest efficacy against *M. persicae* since they had lower mean aphid scores than the rest of the aphicidal treatments. In the first assessment week these three treatments were comparable to the standard aphicides actara and had aphid scores even lower than the standard aphicide confidor suggesting that these aphicides were more efficacious than the standard confidor. Of these effective aphicides, thiamethaxom was the most effective against *M. persicae* followed by imidacloprid and then fipronil (500 ml$Ha^{-1}$). Highest *M. persicae* population in the tobacco leaves was recorded in acetamiprid the higher rate (45 g.100$L^{-1}$) showing that it was not all effective against *M. persicae* in this assessment week (Fig. 10).

In the second assessment week as well thiamethaxom was exhibiting highest efficacy levels against *M. persicae* indicating a significant control of the aphids at this period. However still there is significant aphid control with the same treatments fipronil (500 $ml.Ha^{-1}$), imidacloprid 350 SC showing exceptional aphid control with aphid scores comparable to the two standard aphicides. For the rest of the treatments similarly no significant aphid control is observed as the treatments are comparable to the untreated control and differ significantly from the two standard aphicides indicating low levels of efficacy against *M. persicae*. At this point highest population of *M. persicae* in the tobacco leaves were recorded in the highest rate of fipronil (1000$ml.Ha^{-1}$) indicating no significant control against *M. persicae* (Fig. 11).

At the third and fourth assessment week, significant aphid control is observed among the same treatments thiamethaxom, imidacloprid 350 SC, and fipronil lower rate. These three aphicidal treatments are showing the best perfomance since they are still comparable to the standard aphicides but a negative control is observed in the rest of the treatments which are still attaining aphid scores as high as the untreated control. However a decrease in aphid score is observed for thiamethaxom compared to that at 9WAP indicating a long residual activity. In this case highest aphid scores have been observed in acetamiprid the middle rate (30$g.100L^{-1}$) and calypso the lower rate (30 $ml.100L^{-1}$) for both 10WAP and 11WAP respectively, indicating no efficacy at all against *M. persicae*.

Generally in this trial for all the four assessment weeks, it has been shown that increasing the rate of application of fipronil resulted in higher aphid scores and this could be attributed to unexplained error that could have occurred during dilution of the aphicides or application. The lower efficacy potential exhibited by the higher rates of calypso and fipronil in this trial do not comply with what has been suggested by Matthews (1992) that the use of high doses increases the likelihood that potentially significant toxic effects would be exhibited in the pest being controlled.

The experiment has also complied with what Duan *et al.* (2001) said that the chloro-nicotinyls acetamiprid and thiacloprid have a slower mode of action as planting-hole chemicals as they gave high aphid scores throughout all the assessment weeks (Figs. 10-13).

In contrast, the rest of the aphicides were less efficacious than the standard aphicides, with high aphid populations almost comparable to those of the untreated control. Treatments acetamiprid at 45 g.100L$^{-1}$, calypso at 120 ml.100 L$^{-1}$, fipronil at 1000 ml.100 L$^{-1}$ and imidacloprid 200 SL were not at all effective showing in some cases infestations higher than the untreated control. The low aphid control results shown for imidacloprid200 SL throughout have contrasted with a trial by Cristionin (1997) as well as Sannino and Piro (1998) where results attained showed imidacloprid 200 SL having aphid control capability.

The low residual effect in Acetamiprid and thiacloprid shown by their having highest aphid scores in all the assessment weeks can be attributed to their low persistence in soil (PAN AP, 2011). Mullins *et al.* (1993), argues that persistence of an insecticide in soil allows for continual availability for uptake by plant roots. Thus the low persistence of insecticidal compounds acetamiprid and thiacloprid in soil could have inhibited the continuous availability of the insecticide for uptake by the plant roots, therefore the high aphid score population observed on plots treated by these two compounds in all the assessment weeks. At the last assessment we are still observing thiamethaxom having a consistent aphid score which is an indication of a high residual activity and this conferred well with what has been said by PAN AP (2011), that thiamethaxom has a higher persistence in soil such that residues can be detected in succeeding crops. Imidacloprid 350 SC has also been seen to be highly efficacious against *M. persicae* which can be explained by its high persistence in soil of more than 30 months.

**5.2 Application rates**

In an experiment to determine the optimum rate of control all the three application rates for acetamiprid and thiacloprid (calypso), showed no significant difference indicating that the rates used were either too high or too low. However significant differences have been noted between the lower rate of fipronil and the other two rates, showing that the lower rate of fipronil (500 $ml.Ha^{-1}$) can be the ideal application rate of control.

Apart from the properties of an insecticide having influence on its activity, the results obtained could have been influenced by external factors such as pH as well as use of organic fertilizers as proposed by Sarkar *et al.* (2001). The activity of these insecticides under field conditions in this trial could also have been influenced the unexplained error that could have occurred either during weighing the insecticide or during mixing and application.

**5.3 Conclusion and recommendations**

In this study significant aphid control has been achieved in chloro-nicotinyl insecticides thiamethaxom at its rate $125ml100L^{-1}$ and Imidacloprid 350SC ($170ml.100^{-1}$) which have shown to have a higher efficacy against tobacco aphids. For fipronil the lower rate ($500mlHa^{-1}$) has been shown to be effective in this study in controlling *M.persicae.* However the rest of the aphicides have shown low efficacy as chemical control against *M.persicae* applied as soil applications.

More detailed research should be done in determining the efficacy of imidacloprid 200 SL, calypso and acetamiprid at all the three rates as soil applications. Fipronil should also be taken for another trial to determine the effective rate of control for aphids as soil applications.

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**APPENDICES**

**Appendix 1 Table of mean aphid scores per each treatment for each assessment week**

| TREATMENT | WEEKS AFTER PLANTING | | | |
|---|---|---|---|---|
| | 8 WAP | 9 WAP | 10 WAP | 11WAP |
| 1 | 1.41 | 1.79 | 2.57 | 2.61 |
| 2 | 0.07 | 0.34 | 0.85 | 0.60 |
| 3 | 0.39 | 0.06 | 0.42 | 0.28 |
| 4 | 0.06 | 0.24 | 0.83 | 0.50 |
| 5 | 1.20 | 1.80 | 2.03 | 2.44 |
| 6 | 0.03 | 0.53 | 1.02 | 1.21 |
| 10 | 0.18 | 0.73 | 0.99 | 1.14 |
| 11 | 1.14 | 1.30 | 2.09 | 1.83 |
| 12 | 1.00 | 1.87 | 2.06 | 2.08 |
| 13 | 1.29 | 1.72 | 2.20 | 2.55 |
| 14 | 1.34 | 1.62 | 2.28 | 2.22 |
| 15 | 1.46 | 1.47 | 2.04 | 2.00 |
| 16 | 1.15 | 1.60 | 2.10 | 2.08 |
| 17 | 1.28 | 1.61 | 2.44 | 2.16 |
| 18 | 1.47 | 1.69 | 2.19 | 2.21 |
| | | | | |
| F-PROBABILITY | <.001 | <.001 | <.001 | <.001 |
| S.E.D | 0.24 | 0.23 | 0.40 | 0.31 |
| L.S.D | 0.52 | 0.50 | 0.86 | 0.66 |
| CV (%) | 26.80 | 18.90 | 23.10 | 17.90 |

**APPENDIX 2**

**SPSS Analysis of the results at 8Weeks After Planting (WAP)**

**Tests of Between-Subjects Effects**

Dependent Variable: avg score

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 9.219(a) | 15 | .615 | 12.967 | .000 |
| Intercept | 22.276 | 1 | 22.276 | 470.003 | .000 |
| Treatment | 9.215 | 14 | .658 | 13.888 | .000 |
| Block | .001 | 1 | .001 | .020 | .888 |
| Error | .664 | 14 | .047 | | |
| Total | 34.096 | 30 | | | |
| Corrected Total | 9.883 | 29 | | | |

a R Squared = .933 (Adjusted R Squared = .861)

**Post Hoc Tests**

**treatment**

**Pairwise Comparisons**

Dependent Variable: avg score

| (I) treatment | (J) treatment | Mean Difference | Std. Error | Sig.(a) | 95% Confidence Interval for Difference(a) |
|---|---|---|---|---|---|

| | | (I-J) | | | | |
|---|---|---|---|---|---|---|
| | | Lower Bound | Upper Bound | Lower Bound | Upper Bound | Lower Bound |
| 1 | 2 | 1.338(*) | .218 | .000 | .871 | 1.805 |
| | 3 | 1.014(*) | .218 | .000 | .547 | 1.480 |
| | 4 | 1.343(*) | .218 | .000 | .876 | 1.810 |
| | 5 | .203 | .218 | .368 | -.264 | .669 |
| | 6 | 1.372(*) | .218 | .000 | .905 | 1.839 |
| | 7 | 1.230(*) | .218 | .000 | .763 | 1.697 |
| | 8 | .261 | .218 | .251 | -.206 | .728 |
| | 9 | .401 | .218 | .087 | -.066 | .868 |
| | 10 | .116 | .218 | .603 | -.351 | .583 |
| | 11 | .068 | .218 | .759 | -.399 | .535 |
| | 12 | -.055 | .218 | .804 | -.522 | .412 |
| | 13 | .255 | .218 | .262 | -.212 | .722 |
| | 14 | .411 | .270 | .149 | -.167 | .990 |
| | 15 | -.094 | .199 | .643 | -.522 | .333 |
| 2 | 1 | -1.338(*) | .218 | .000 | -1.805 | -.871 |
| | 3 | -.325 | .218 | .158 | -.792 | .142 |
| | 4 | .005 | .218 | .983 | -.462 | .472 |
| | 5 | -1.136(*) | .218 | .000 | -1.603 | -.669 |
| | 6 | .034 | .218 | .878 | -.433 | .501 |
| | 7 | -.109 | .218 | .626 | -.575 | .358 |
| | 8 | -1.078(*) | .218 | .000 | -1.545 | -.611 |
| | 9 | -.937(*) | .218 | .001 | -1.404 | -.470 |
| | 10 | -1.222(*) | .218 | .000 | -1.689 | -.756 |
| | 11 | -1.270(*) | .218 | .000 | -1.737 | -.803 |
| | 12 | -1.393(*) | .218 | .000 | -1.860 | -.926 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 13 | -1.084(*) | .218 | .000 | -1.551 | -.617 |
| | 14 | -.927(*) | .270 | .004 | -1.505 | -.348 |
| | 15 | -1.433(*) | .199 | .000 | -1.860 | -1.006 |
| 3 | 1 | -1.014(*) | .218 | .000 | -1.480 | -.547 |
| | 2 | .325 | .218 | .158 | -.142 | .792 |
| | 4 | .330 | .218 | .152 | -.137 | .797 |
| | 5 | -.811(*) | .218 | .002 | -1.278 | -.344 |
| | 6 | .359 | .218 | .122 | -.108 | .826 |
| | 7 | .216 | .218 | .337 | -.251 | .683 |
| | 8 | -.753(*) | .218 | .004 | -1.220 | -.286 |
| | 9 | -.612(*) | .218 | .014 | -1.079 | -.145 |
| | 10 | -.898(*) | .218 | .001 | -1.365 | -.431 |
| | 11 | -.945(*) | .218 | .001 | -1.412 | -.478 |
| | 12 | -1.069(*) | .218 | .000 | -1.535 | -.602 |
| | 13 | -.759(*) | .218 | .004 | -1.226 | -.292 |
| | 14 | -.602(*) | .270 | .042 | -1.181 | -.024 |
| | 15 | -1.108(*) | .199 | .000 | -1.535 | -.681 |
| 4 | 1 | -1.343(*) | .218 | .000 | -1.810 | -.876 |
| | 2 | -.005 | .218 | .983 | -.472 | .462 |
| | 3 | -.330 | .218 | .152 | -.797 | .137 |
| | 5 | -1.141(*) | .218 | .000 | -1.608 | -.674 |
| | 6 | .029 | .218 | .895 | -.438 | .496 |
| | 7 | -.113 | .218 | .611 | -.580 | .354 |
| | 8 | -1.082(*) | .218 | .000 | -1.549 | -.615 |
| | 9 | -.942(*) | .218 | .001 | -1.409 | -.475 |
| | 10 | -1.227(*) | .218 | .000 | -1.694 | -.760 |
| | 11 | -1.275(*) | .218 | .000 | -1.742 | -.808 |
| | 12 | -1.398(*) | .218 | .000 | -1.865 | -.931 |
| | 13 | -1.089(*) | .218 | .000 | -1.556 | -.622 |
| | 14 | -.932(*) | .270 | .004 | -1.510 | -.353 |
| | 15 | -1.438(*) | .199 | .000 | -1.865 | -1.010 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 1 | -.203 | .218 | .368 | -.669 | .264 |
| | 2 | 1.136(*) | .218 | .000 | .669 | 1.603 |
| | 3 | .811(*) | .218 | .002 | .344 | 1.278 |
| | 4 | 1.141(*) | .218 | .000 | .674 | 1.608 |
| | 6 | 1.170(*) | .218 | .000 | .703 | 1.637 |
| | 7 | 1.027(*) | .218 | .000 | .560 | 1.494 |
| | 8 | .058 | .218 | .793 | -.409 | .525 |
| | 9 | .199 | .218 | .377 | -.268 | .666 |
| | 10 | -.087 | .218 | .696 | -.554 | .380 |
| | 11 | -.134 | .218 | .547 | -.601 | .333 |
| | 12 | -.258 | .218 | .256 | -.724 | .209 |
| | 13 | .052 | .218 | .815 | -.415 | .519 |
| | 14 | .209 | .270 | .451 | -.370 | .787 |
| | 15 | -.297 | .199 | .158 | -.724 | .130 |
| 6 | 1 | -1.372(*) | .218 | .000 | -1.839 | -.905 |
| | 2 | -.034 | .218 | .878 | -.501 | .433 |
| | 3 | -.359 | .218 | .122 | -.826 | .108 |
| | 4 | -.029 | .218 | .895 | -.496 | .438 |
| | 5 | -1.170(*) | .218 | .000 | -1.637 | -.703 |
| | 7 | -.143 | .218 | .523 | -.610 | .324 |
| | 8 | -1.112(*) | .218 | .000 | -1.579 | -.645 |
| | 9 | -.971(*) | .218 | .001 | -1.438 | -.504 |
| | 10 | -1.256(*) | .218 | .000 | -1.723 | -.790 |
| | 11 | -1.304(*) | .218 | .000 | -1.771 | -.837 |
| | 12 | -1.427(*) | .218 | .000 | -1.894 | -.960 |
| | 13 | -1.118(*) | .218 | .000 | -1.585 | -.651 |
| | 14 | -.961(*) | .270 | .003 | -1.539 | -.382 |
| | 15 | -1.467(*) | .199 | .000 | -1.894 | -1.040 |
| 7 | 1 | -1.230(*) | .218 | .000 | -1.697 | -.763 |
| | 2 | .109 | .218 | .626 | -.358 | .575 |
| | 3 | -.216 | .218 | .337 | -.683 | .251 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 4 | .113 | .218 | .611 | -.354 | .580 |
| | 5 | -1.027(*) | .218 | .000 | -1.494 | -.560 |
| | 6 | .143 | .218 | .523 | -.324 | .610 |
| | 8 | -.969(*) | .218 | .001 | -1.436 | -.502 |
| | 9 | -.829(*) | .218 | .002 | -1.295 | -.362 |
| | 10 | -1.114(*) | .218 | .000 | -1.581 | -.647 |
| | 11 | -1.162(*) | .218 | .000 | -1.629 | -.695 |
| | 12 | -1.285(*) | .218 | .000 | -1.752 | -.818 |
| | 13 | -.975(*) | .218 | .001 | -1.442 | -.508 |
| | 14 | -.818(*) | .270 | .009 | -1.397 | -.240 |
| | 15 | -1.324(*) | .199 | .000 | -1.751 | -.897 |
| 8 | 1 | -.261 | .218 | .251 | -.728 | .206 |
| | 2 | 1.078(*) | .218 | .000 | .611 | 1.545 |
| | 3 | .753(*) | .218 | .004 | .286 | 1.220 |
| | 4 | 1.082(*) | .218 | .000 | .615 | 1.549 |
| | 5 | -.058 | .218 | .793 | -.525 | .409 |
| | 6 | 1.112(*) | .218 | .000 | .645 | 1.579 |
| | 7 | .969(*) | .218 | .001 | .502 | 1.436 |
| | 9 | .140 | .218 | .529 | -.326 | .607 |
| | 10 | -.145 | .218 | .517 | -.612 | .322 |
| | 11 | -.193 | .218 | .391 | -.660 | .274 |
| | 12 | -.316 | .218 | .169 | -.783 | .151 |
| | 13 | -.006 | .218 | .978 | -.473 | .461 |
| | 14 | .151 | .270 | .585 | -.428 | .729 |
| | 15 | -.355 | .199 | .096 | -.782 | .072 |
| 9 | 1 | -.401 | .218 | .087 | -.868 | .066 |
| | 2 | .937(*) | .218 | .001 | .470 | 1.404 |
| | 3 | .612(*) | .218 | .014 | .145 | 1.079 |
| | 4 | .942(*) | .218 | .001 | .475 | 1.409 |
| | 5 | -.199 | .218 | .377 | -.666 | .268 |
| | 6 | .971(*) | .218 | .001 | .504 | 1.438 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 7 | .829(*) | .218 | .002 | .362 | 1.295 |
| | 8 | -.140 | .218 | .529 | -.607 | .326 |
| | 10 | -.285 | .218 | .211 | -.752 | .182 |
| | 11 | -.333 | .218 | .148 | -.800 | .134 |
| | 12 | -.456 | .218 | .055 | -.923 | .011 |
| | 13 | -.147 | .218 | .512 | -.614 | .320 |
| | 14 | .010 | .270 | .970 | -.568 | .589 |
| | 15 | -.496(*) | .199 | .026 | -.923 | -.068 |
| 10 | 1 | -.116 | .218 | .603 | -.583 | .351 |
| | 2 | 1.222(*) | .218 | .000 | .756 | 1.689 |
| | 3 | .898(*) | .218 | .001 | .431 | 1.365 |
| | 4 | 1.227(*) | .218 | .000 | .760 | 1.694 |
| | 5 | .087 | .218 | .696 | -.380 | .554 |
| | 6 | 1.256(*) | .218 | .000 | .790 | 1.723 |
| | 7 | 1.114(*) | .218 | .000 | .647 | 1.581 |
| | 8 | .145 | .218 | .517 | -.322 | .612 |
| | 9 | .285 | .218 | .211 | -.182 | .752 |
| | 11 | -.048 | .218 | .830 | -.515 | .419 |
| | 12 | -.171 | .218 | .446 | -.638 | .296 |
| | 13 | .139 | .218 | .534 | -.328 | .606 |
| | 14 | .296 | .270 | .292 | -.283 | .874 |
| | 15 | -.210 | .199 | .309 | -.638 | .217 |
| 11 | 1 | -.068 | .218 | .759 | -.535 | .399 |
| | 2 | 1.270(*) | .218 | .000 | .803 | 1.737 |
| | 3 | .945(*) | .218 | .001 | .478 | 1.412 |
| | 4 | 1.275(*) | .218 | .000 | .808 | 1.742 |
| | 5 | .134 | .218 | .547 | -.333 | .601 |
| | 6 | 1.304(*) | .218 | .000 | .837 | 1.771 |
| | 7 | 1.162(*) | .218 | .000 | .695 | 1.629 |
| | 8 | .193 | .218 | .391 | -.274 | .660 |
| | 9 | .333 | .218 | .148 | -.134 | .800 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 10 | .048 | .218 | .830 | -.419 | .515 |
| | 12 | -.123 | .218 | .580 | -.590 | .344 |
| | 13 | .186 | .218 | .406 | -.281 | .653 |
| | 14 | .343 | .270 | .224 | -.235 | .922 |
| | 15 | -.163 | .199 | .428 | -.590 | .265 |
| 12 | 1 | .055 | .218 | .804 | -.412 | .522 |
| | 2 | 1.393(*) | .218 | .000 | .926 | 1.860 |
| | 3 | 1.069(*) | .218 | .000 | .602 | 1.535 |
| | 4 | 1.398(*) | .218 | .000 | .931 | 1.865 |
| | 5 | .258 | .218 | .256 | -.209 | .724 |
| | 6 | 1.427(*) | .218 | .000 | .960 | 1.894 |
| | 7 | 1.285(*) | .218 | .000 | .818 | 1.752 |
| | 8 | .316 | .218 | .169 | -.151 | .783 |
| | 9 | .456 | .218 | .055 | -.011 | .923 |
| | 10 | .171 | .218 | .446 | -.296 | .638 |
| | 11 | .123 | .218 | .580 | -.344 | .590 |
| | 13 | .310 | .218 | .177 | -.157 | .777 |
| | 14 | .466 | .270 | .106 | -.112 | 1.045 |
| | 15 | -.039 | .199 | .846 | -.467 | .388 |
| 13 | 1 | -.255 | .218 | .262 | -.722 | .212 |
| | 2 | 1.084(*) | .218 | .000 | .617 | 1.551 |
| | 3 | .759(*) | .218 | .004 | .292 | 1.226 |
| | 4 | 1.089(*) | .218 | .000 | .622 | 1.556 |
| | 5 | -.052 | .218 | .815 | -.519 | .415 |
| | 6 | 1.118(*) | .218 | .000 | .651 | 1.585 |
| | 7 | .975(*) | .218 | .001 | .508 | 1.442 |
| | 8 | .006 | .218 | .978 | -.461 | .473 |
| | 9 | .147 | .218 | .512 | -.320 | .614 |
| | 10 | -.139 | .218 | .534 | -.606 | .328 |
| | 11 | -.186 | .218 | .406 | -.653 | .281 |
| | 12 | -.310 | .218 | .177 | -.777 | .157 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 14 | .157 | .270 | .570 | -.422 | .735 |
| | 15 | -.349 | .199 | .102 | -.776 | .078 |
| 14 | 1 | -.411 | .270 | .149 | -.990 | .167 |
| | 2 | .927(*) | .270 | .004 | .348 | 1.505 |
| | 3 | .602(*) | .270 | .042 | .024 | 1.181 |
| | 4 | .932(*) | .270 | .004 | .353 | 1.510 |
| | 5 | -.209 | .270 | .451 | -.787 | .370 |
| | 6 | .961(*) | .270 | .003 | .382 | 1.539 |
| | 7 | .818(*) | .270 | .009 | .240 | 1.397 |
| | 8 | -.151 | .270 | .585 | -.729 | .428 |
| | 9 | -.010 | .270 | .970 | -.589 | .568 |
| | 10 | -.296 | .270 | .292 | -.874 | .283 |
| | 11 | -.343 | .270 | .224 | -.922 | .235 |
| | 12 | -.466 | .270 | .106 | -1.045 | .112 |
| | 13 | -.157 | .270 | .570 | -.735 | .422 |
| | 15 | -.506 | .257 | .069 | -1.058 | .046 |
| 15 | 1 | .094 | .199 | .643 | -.333 | .522 |
| | 2 | 1.433(*) | .199 | .000 | 1.006 | 1.860 |
| | 3 | 1.108(*) | .199 | .000 | .681 | 1.535 |
| | 4 | 1.438(*) | .199 | .000 | 1.010 | 1.865 |
| | 5 | .297 | .199 | .158 | -.130 | .724 |
| | 6 | 1.467(*) | .199 | .000 | 1.040 | 1.894 |
| | 7 | 1.324(*) | .199 | .000 | .897 | 1.751 |
| | 8 | .355 | .199 | .096 | -.072 | .782 |
| | 9 | .496(*) | .199 | .026 | .068 | .923 |
| | 10 | .210 | .199 | .309 | -.217 | .638 |
| | 11 | .163 | .199 | .428 | -.265 | .590 |
| | 12 | .039 | .199 | .846 | -.388 | .467 |
| | 13 | .349 | .199 | .102 | -.078 | .776 |
| | 14 | .506 | .257 | .069 | -.046 | 1.058 |

Based on estimated marginal means

* The mean difference is significant at the .05 level

a Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustme

**APPENDIX 3**

**SPSS Analysis of the results at9 Weeks After Planting (WAP)**

**Tests of Between-Subjects Effects**

Dependent Variable: avg score

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 12.334(a) | 15 | .822 | 15.408 | .000 |
| Intercept | 45.024 | 1 | 45.024 | 843.698 | .000 |
| Treatment | 11.710 | 14 | .836 | 15.674 | .000 |
| Block | .624 | 1 | .624 | 11.686 | .004 |
| Error | .747 | 14 | .053 | | |
| Total | 58.105 | 30 | | | |
| Corrected Total | 13.081 | 29 | | | |

a R Squared = .943 (Adjusted R Squared = .882)

**Post Hoc Tests**

**Treatment**

**Multiple Comparisons**

Dependent Variable: avg score

Tukey HSD

| | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| (I) treatment | (J) treatment | Lower Bound | Upper Bound | Lower Bound | Upper Bound | Lower Bound |
| 1 | 2 | 1.450887(*) | .2310086 | .001 | .517528 | 2.384246 |
| | 3 | 1.726349(*) | .2310086 | .000 | .792990 | 2.659708 |
| | 4 | 1.552458(*) | .2310086 | .001 | .619099 | 2.485817 |
| | 5 | -.006010 | .2310086 | 1.000 | -.939368 | .927349 |
| | 6 | 1.257532(*) | .2310086 | .005 | .324173 | 2.190891 |
| | 7 | 1.059011(*) | .2310086 | .020 | .125652 | 1.992369 |
| | 8 | .486699 | .2310086 | .714 | -.446660 | 1.420058 |
| | 9 | -.076646 | .2310086 | 1.000 | -1.010005 | .856713 |
| | 10 | .068822 | .2310086 | 1.000 | -.864537 | 1.002181 |
| | 11 | .171074 | .2310086 | 1.000 | -.762285 | 1.104433 |
| | 12 | .316067 | .2310086 | .978 | -.617292 | 1.249426 |
| | 13 | .195204 | .2310086 | 1.000 | -.738155 | 1.128562 |
| | 14 | .181490 | .2310086 | 1.000 | -.751868 | 1.114849 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 15 | .103991 | .2310086 | 1.000 | -.829368 | 1.037350 |
| 2 | 1 | -1.450887(*) | .2310086 | .001 | -2.384246 | -.517528 |
| | 3 | .275462 | .2310086 | .993 | -.657897 | 1.208821 |
| | 4 | .101571 | .2310086 | 1.000 | -.831788 | 1.034930 |
| | 5 | -1.456897(*) | .2310086 | .001 | -2.390255 | -.523538 |
| | 6 | -.193355 | .2310086 | 1.000 | -1.126714 | .740004 |
| | 7 | -.391876 | .2310086 | .903 | -1.325235 | .541482 |
| | 8 | -.964188(*) | .2310086 | .040 | -1.897547 | -.030829 |
| | 9 | -1.527533(*) | .2310086 | .001 | -2.460892 | -.594174 |
| | 10 | -1.382065(*) | .2310086 | .002 | -2.315423 | -.448706 |
| | 11 | -1.279813(*) | .2310086 | .004 | -2.213172 | -.346454 |
| | 12 | -1.134820(*) | .2310086 | .011 | -2.068179 | -.201461 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 13 | -1.255683(*) | .2310086 | .005 | -2.189042 | -.322325 |
| | 14 | -1.269397(*) | .2310086 | .004 | -2.202755 | -.336038 |
| | 15 | -1.346896(*) | .2310086 | .002 | -2.280255 | -.413537 |
| 3 | 1 | -1.726349(*) | .2310086 | .000 | -2.659708 | -.792990 |
| | 2 | -.275462 | .2310086 | .993 | -1.208821 | .657897 |
| | 4 | -.173891 | .2310086 | 1.000 | -1.107250 | .759468 |
| | 5 | -1.732359(*) | .2310086 | .000 | -2.665718 | -.799000 |
| | 6 | -.468817 | .2310086 | .756 | -1.402176 | .464542 |
| | 7 | -.667339 | .2310086 | .304 | -1.600698 | .266020 |
| | 8 | -1.239651(*) | .2310086 | .005 | -2.173009 | -.306292 |
| | 9 | -1.802995(*) | .2310086 | .000 | -2.736354 | -.869637 |
| | 10 | -1.657527( | .2310086 | .000 | -2.590886 | -.724168 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | *) | | | | |
| | 11 | -1.555276(*) | .2310086 | .001 | -2.488634 | -.621917 |
| | 12 | -1.410282(*) | .2310086 | .002 | -2.343641 | -.476923 |
| | 13 | -1.531146(*) | .2310086 | .001 | -2.464505 | -.597787 |
| | 14 | -1.544859(*) | .2310086 | .001 | -2.478218 | -.611500 |
| | 15 | -1.622358(*) | .2310086 | .000 | -2.555717 | -.688999 |
| 4 | 1 | -1.552458(*) | .2310086 | .001 | -2.485817 | -.619099 |
| | 2 | -.101571 | .2310086 | 1.000 | -1.034930 | .831788 |
| | 3 | .173891 | .2310086 | 1.000 | -.759468 | 1.107250 |
| | 5 | -1.558468(*) | .2310086 | .001 | -2.491827 | -.625109 |
| | 6 | -.294926 | .2310086 | .987 | -1.228285 | .638433 |
| | 7 | -.493448 | .2310086 | .698 | -1.426806 | .439911 |
| | 8 | - | .231008 | .019 | -1.999118 | -.132401 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | 1.065759(*) | 6 | | | |
| | 9 | -1.629104(*) | .2310086 | .000 | -2.562463 | -.695745 |
| | 10 | -1.483636(*) | .2310086 | .001 | -2.416995 | -.550277 |
| | 11 | -1.381384(*) | .2310086 | .002 | -2.314743 | -.448026 |
| | 12 | -1.236391(*) | .2310086 | .005 | -2.169750 | -.303032 |
| | 13 | -1.357255(*) | .2310086 | .002 | -2.290613 | -.423896 |
| | 14 | -1.370968(*) | .2310086 | .002 | -2.304327 | -.437609 |
| | 15 | -1.448467(*) | .2310086 | .001 | -2.381826 | -.515108 |
| 5 | 1 | .006010 | .2310086 | 1.000 | -.927349 | .939368 |
| | 2 | 1.456897(*) | .2310086 | .001 | .523538 | 2.390255 |
| | 3 | 1.732359(*) | .2310086 | .000 | .799000 | 2.665718 |
| | 4 | 1.558468(*) | .2310086 | .001 | .625109 | 2.491827 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 6 | 1.263542(*) | .2310086 | .004 | .330183 | 2.196901 |
| | 7 | 1.065020(*) | .2310086 | .019 | .131661 | 1.998379 |
| | 8 | .492708 | .2310086 | .700 | -.440651 | 1.426067 |
| | 9 | -.070637 | .2310086 | 1.000 | -1.003995 | .862722 |
| | 10 | .074832 | .2310086 | 1.000 | -.858527 | 1.008191 |
| | 11 | .177083 | .2310086 | 1.000 | -.756276 | 1.110442 |
| | 12 | .322077 | .2310086 | .974 | -.611282 | 1.255435 |
| | 13 | .201213 | .2310086 | 1.000 | -.732146 | 1.134572 |
| | 14 | .187500 | .2310086 | 1.000 | -.745859 | 1.120859 |
| | 15 | .110001 | .2310086 | 1.000 | -.823358 | 1.043360 |
| 6 | 1 | -1.257532(*) | .2310086 | .005 | -2.190891 | -.324173 |
| | 2 | .193355 | .2310086 | 1.000 | -.740004 | 1.126714 |
| | 3 | .468817 | .2310086 | .756 | -.464542 | 1.402176 |
| | 4 | .294926 | .2310086 | .987 | -.638433 | 1.228285 |
| | 5 | -1.263542( | .2310086 | .004 | -2.196901 | -.330183 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | *) | | | | |
| | 7 | -.198522 | .2310086 | 1.000 | -1.131880 | .734837 |
| | 8 | -.770833 | .2310086 | .158 | -1.704192 | .162526 |
| | 9 | -1.334178(*) | .2310086 | .003 | -2.267537 | -.400819 |
| | 10 | -1.188710(*) | .2310086 | .008 | -2.122069 | -.255351 |
| | 11 | -1.086458(*) | .2310086 | .016 | -2.019817 | -.153099 |
| | 12 | -.941465(*) | .2310086 | .047 | -1.874824 | -.008106 |
| | 13 | -1.062329(*) | .2310086 | .019 | -1.995687 | -.128970 |
| | 14 | -1.076042(*) | .2310086 | .017 | -2.009401 | -.142683 |
| | 15 | -1.153541(*) | .2310086 | .010 | -2.086900 | -.220182 |
| 7 | 1 | -1.059011(*) | .2310086 | .020 | -1.992369 | -.125652 |
| | 2 | .391876 | .2310086 | .903 | -.541482 | 1.325235 |

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|---|---|---|---|---|---|---|
| | 3 | .667339 | .2310086 | .304 | -.266020 | 1.600698 |
| | 4 | .493448 | .2310086 | .698 | -.439911 | 1.426806 |
| | 5 | -1.065020(*) | .2310086 | .019 | -1.998379 | -.131661 |
| | 6 | .198522 | .2310086 | 1.000 | -.734837 | 1.131880 |
| | 8 | -.572312 | .2310086 | .505 | -1.505671 | .361047 |
| | 9 | -1.135657(*) | .2310086 | .011 | -2.069016 | -.202298 |
| | 10 | -.990188(*) | .2310086 | .033 | -1.923547 | -.056829 |
| | 11 | -.887937 | .2310086 | .070 | -1.821296 | .045422 |
| | 12 | -.742944 | .2310086 | .190 | -1.676302 | .190415 |
| | 13 | -.863807 | .2310086 | .083 | -1.797166 | .069552 |
| | 14 | -.877520 | .2310086 | .075 | -1.810879 | .055839 |
| | 15 | -.955019(*) | .2310086 | .043 | -1.888378 | -.021661 |
| 8 | 1 | -.486699 | .2310086 | .714 | -1.420058 | .446660 |
| | 2 | .964188(* | .231008 | .040 | .030829 | 1.897547 |

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|---|---|---|---|---|---|---|
| | | ) | 6 | | | |
| | 3 | 1.239651(*) | .2310086 | .005 | .306292 | 2.173009 |
| | 4 | 1.065759(*) | .2310086 | .019 | .132401 | 1.999118 |
| | 5 | -.492708 | .2310086 | .700 | -1.426067 | .440651 |
| | 6 | .770833 | .2310086 | .158 | -.162526 | 1.704192 |
| | 7 | .572312 | .2310086 | .505 | -.361047 | 1.505671 |
| | 9 | -.563345 | .2310086 | .526 | -1.496704 | .370014 |
| | 10 | -.417876 | .2310086 | .861 | -1.351235 | .515483 |
| | 11 | -.315625 | .2310086 | .978 | -1.248984 | .617734 |
| | 12 | -.170632 | .2310086 | 1.000 | -1.103991 | .762727 |
| | 13 | -.291495 | .2310086 | .988 | -1.224854 | .641864 |
| | 14 | -.305208 | .2310086 | .983 | -1.238567 | .628151 |
| | 15 | -.382708 | .2310086 | .916 | -1.316067 | .550651 |
| 9 | 1 | .076646 | .2310086 | 1.000 | -.856713 | 1.010005 |
| | 2 | 1.527533(*) | .2310086 | .001 | .594174 | 2.460892 |
| | 3 | 1.802995(*) | .2310086 | .000 | .869637 | 2.736354 |

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|---|---|---|---|---|---|---|
| | 4 | 1.629104(*) | .2310086 | .000 | .695745 | 2.562463 |
| | 5 | .070637 | .2310086 | 1.000 | -.862722 | 1.003995 |
| | 6 | 1.334178(*) | .2310086 | .003 | .400819 | 2.267537 |
| | 7 | 1.135657(*) | .2310086 | .011 | .202298 | 2.069016 |
| | 8 | .563345 | .2310086 | .526 | -.370014 | 1.496704 |
| | 10 | .145469 | .2310086 | 1.000 | -.787890 | 1.078827 |
| | 11 | .247720 | .2310086 | .997 | -.685639 | 1.181079 |
| | 12 | .392713 | .2310086 | .902 | -.540646 | 1.326072 |
| | 13 | .271850 | .2310086 | .994 | -.661509 | 1.205209 |
| | 14 | .258137 | .2310086 | .996 | -.675222 | 1.191495 |
| | 15 | .180637 | .2310086 | 1.000 | -.752722 | 1.113996 |
| 10 | 1 | -.068822 | .2310086 | 1.000 | -1.002181 | .864537 |
| | 2 | 1.382065(*) | .2310086 | .002 | .448706 | 2.315423 |
| | 3 | 1.657527(*) | .2310086 | .000 | .724168 | 2.590886 |
| | 4 | 1.483636(*) | .2310086 | .001 | .550277 | 2.416995 |
| | 5 | -.074832 | .231008 | 1.000 | -1.008191 | .858527 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 6 | | | |
| | 6 | 1.188710(*) | .2310086 | .008 | .255351 | 2.122069 |
| | 7 | .990188(*) | .2310086 | .033 | .056829 | 1.923547 |
| | 8 | .417876 | .2310086 | .861 | -.515483 | 1.351235 |
| | 9 | -.145469 | .2310086 | 1.000 | -1.078827 | .787890 |
| | 11 | .102251 | .2310086 | 1.000 | -.831108 | 1.035610 |
| | 12 | .247245 | .2310086 | .997 | -.686114 | 1.180603 |
| | 13 | .126381 | .2310086 | 1.000 | -.806978 | 1.059740 |
| | 14 | .112668 | .2310086 | 1.000 | -.820691 | 1.046027 |
| | 15 | .035169 | .2310086 | 1.000 | -.898190 | .968528 |
| 11 | 1 | -.171074 | .2310086 | 1.000 | -1.104433 | .762285 |
| | 2 | 1.279813(*) | .2310086 | .004 | .346454 | 2.213172 |
| | 3 | 1.555276(*) | .2310086 | .001 | .621917 | 2.488634 |
| | 4 | 1.381384(*) | .2310086 | .002 | .448026 | 2.314743 |
| | 5 | -.177083 | .2310086 | 1.000 | -1.110442 | .756276 |
| | 6 | 1.086458(*) | .2310086 | .016 | .153099 | 2.019817 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 7 | .887937 | .2310086 | .070 | -.045422 | 1.821296 |
| | 8 | .315625 | .2310086 | .978 | -.617734 | 1.248984 |
| | 9 | -.247720 | .2310086 | .997 | -1.181079 | .685639 |
| | 10 | -.102251 | .2310086 | 1.000 | -1.035610 | .831108 |
| | 12 | .144993 | .2310086 | 1.000 | -.788366 | 1.078352 |
| | 13 | .024130 | .2310086 | 1.000 | -.909229 | .957489 |
| | 14 | .010417 | .2310086 | 1.000 | -.922942 | .943776 |
| | 15 | -.067083 | .2310086 | 1.000 | -1.000442 | .866276 |
| 12 | 1 | -.316067 | .2310086 | .978 | -1.249426 | .617292 |
| | 2 | 1.134820(*) | .2310086 | .011 | .201461 | 2.068179 |
| | 3 | 1.410282(*) | .2310086 | .002 | .476923 | 2.343641 |
| | 4 | 1.236391(*) | .2310086 | .005 | .303032 | 2.169750 |
| | 5 | -.322077 | .2310086 | .974 | -1.255435 | .611282 |
| | 6 | .941465(*) | .2310086 | .047 | .008106 | 1.874824 |
| | 7 | .742944 | .2310086 | .190 | -.190415 | 1.676302 |
| | 8 | .170632 | .231008 | 1.000 | -.762727 | 1.103991 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 6 | | | |
| | 9 | -.392713 | .2310086 | .902 | -1.326072 | .540646 |
| | 10 | -.247245 | .2310086 | .997 | -1.180603 | .686114 |
| | 11 | -.144993 | .2310086 | 1.000 | -1.078352 | .788366 |
| | 13 | -.120863 | .2310086 | 1.000 | -1.054222 | .812495 |
| | 14 | -.134577 | .2310086 | 1.000 | -1.067935 | .798782 |
| | 15 | -.212076 | .2310086 | .999 | -1.145435 | .721283 |
| 13 | 1 | -.195204 | .2310086 | 1.000 | -1.128562 | .738155 |
| | 2 | 1.255683(*) | .2310086 | .005 | .322325 | 2.189042 |
| | 3 | 1.531146(*) | .2310086 | .001 | .597787 | 2.464505 |
| | 4 | 1.357255(*) | .2310086 | .002 | .423896 | 2.290613 |
| | 5 | -.201213 | .2310086 | 1.000 | -1.134572 | .732146 |
| | 6 | 1.062329(*) | .2310086 | .019 | .128970 | 1.995687 |
| | 7 | .863807 | .2310086 | .083 | -.069552 | 1.797166 |
| | 8 | .291495 | .2310086 | .988 | -.641864 | 1.224854 |
| | 9 | -.271850 | .2310086 | .994 | -1.205209 | .661509 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 10 | -.126381 | .2310086 | 1.000 | -1.059740 | .806978 |
| | 11 | -.024130 | .2310086 | 1.000 | -.957489 | .909229 |
| | 12 | .120863 | .2310086 | 1.000 | -.812495 | 1.054222 |
| | 14 | -.013713 | .2310086 | 1.000 | -.947072 | .919646 |
| | 15 | -.091212 | .2310086 | 1.000 | -1.024571 | .842146 |
| 14 | 1 | -.181490 | .2310086 | 1.000 | -1.114849 | .751868 |
| | 2 | 1.269397(*) | .2310086 | .004 | .336038 | 2.202755 |
| | 3 | 1.544859(*) | .2310086 | .001 | .611500 | 2.478218 |
| | 4 | 1.370968(*) | .2310086 | .002 | .437609 | 2.304327 |
| | 5 | -.187500 | .2310086 | 1.000 | -1.120859 | .745859 |
| | 6 | 1.076042(*) | .2310086 | .017 | .142683 | 2.009401 |
| | 7 | .877520 | .2310086 | .075 | -.055839 | 1.810879 |
| | 8 | .305208 | .2310086 | .983 | -.628151 | 1.238567 |
| | 9 | -.258137 | .2310086 | .996 | -1.191495 | .675222 |
| | 10 | -.112668 | .2310086 | 1.000 | -1.046027 | .820691 |
| | 11 | -.010417 | .231008 | 1.000 | -.943776 | .922942 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 6 | | | |
| | 12 | .134577 | .2310086 | 1.000 | -.798782 | 1.067935 |
| | 13 | .013713 | .2310086 | 1.000 | -.919646 | .947072 |
| | 15 | -.077499 | .2310086 | 1.000 | -1.010858 | .855860 |
| 15 | 1 | -.103991 | .2310086 | 1.000 | -1.037350 | .829368 |
| | 2 | 1.346896(*) | .2310086 | .002 | .413537 | 2.280255 |
| | 3 | 1.622358(*) | .2310086 | .000 | .688999 | 2.555717 |
| | 4 | 1.448467(*) | .2310086 | .001 | .515108 | 2.381826 |
| | 5 | -.110001 | .2310086 | 1.000 | -1.043360 | .823358 |
| | 6 | 1.153541(*) | .2310086 | .010 | .220182 | 2.086900 |
| | 7 | .955019(*) | .2310086 | .043 | .021661 | 1.888378 |
| | 8 | .382708 | .2310086 | .916 | -.550651 | 1.316067 |
| | 9 | -.180637 | .2310086 | 1.000 | -1.113996 | .752722 |
| | 10 | -.035169 | .2310086 | 1.000 | -.968528 | .898190 |
| | 11 | .067083 | .2310086 | 1.000 | -.866276 | 1.000442 |
| | 12 | .212076 | .2310086 | .999 | -.721283 | 1.145435 |

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|---|---|---|---|---|---|
| 13 | .091212 | .2310086 | 1.000 | -.842146 | 1.024571 |
| 14 | .077499 | .2310086 | 1.000 | -.855860 | 1.010858 |

Based on observed means. The mean difference is significant at the .05 level.

**APPENDEX 4**

**SPSS Analysis of the results at10 weeks after planting (WAP)**

**Tests of Between-Subjects Effects**

Dependent Variable: avg score

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 13.988(a) | 15 | .933 | 5.764 | .001 |
| Intercept | 90.876 | 1 | 90.876 | 561.712 | .000 |
| Treatment | 13.767 | 14 | .983 | 6.078 | .001 |
| Block | .221 | 1 | .221 | 1.366 | .262 |
| Error | 2.265 | 14 | .162 | | |
| Total | 107.128 | 30 | | | |
| Corrected Total | 16.253 | 29 | | | |

a R Squared = .861 (Adjusted R Squared = .711)

**Post Hoc Tests**

**Treatment**

**Multiple Comparisons**

Dependent Variable: avg score

Tukey HSD

| | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| (I) treatment | (J) treatment | Lower Bound | Upper Bound | Lower Bound | Upper Bound | Lower Bound |
| 1 | 2 | 1.7215269 (*) | .40222313 | .033 | .0963988 | 3.3466549 |
| | 3 | 2.1496588 (*) | .40222313 | .005 | .5245307 | 3.7747869 |
| | 4 | 1.7403846 (*) | .40222313 | .031 | .1152566 | 3.3655127 |
| | 5 | .5372596 | .40222313 | .982 | -1.0878684 | 2.1623877 |
| | 6 | 1.5529182 | .40222313 | .068 | -.0722098 | 3.1780463 |
| | 7 | 1.5810096 | .40222313 | .060 | -.0441184 | 3.2061377 |
| | 8 | .4743067 | .40222313 | .994 | -1.1508213 | 2.0994348 |
| | 9 | .5097539 | .40222313 | .988 | -1.1153742 | 2.1348819 |
| | 10 | .3668967 | .40222313 | .999 | -1.2582313 | 1.9920248 |
| | 11 | .2841346 | .40222313 | 1.000 | -1.3409934 | 1.9092627 |
| | 12 | .5258013 | .40222313 | .985 | -1.0993268 | 2.1509293 |
| | 13 | .4639490 | .40222313 | .995 | -1.1611791 | 2.0890771 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 14 | .1310096 | .40222313 | 1.000 | -1.4941184 | 1.7561377 |
| | 15 | .3821915 | .40222313 | .999 | -1.2429366 | 2.0073195 |
| 2 | 1 | -1.7215269(*) | .40222313 | .033 | -3.3466549 | -.0963988 |
| | 3 | .4281320 | .40222313 | .998 | -1.1969961 | 2.0532600 |
| | 4 | .0188578 | .40222313 | 1.000 | -1.6062703 | 1.6439858 |
| | 5 | -1.1842672 | .40222313 | .281 | -2.8093953 | .4408608 |
| | 6 | -.1686086 | .40222313 | 1.000 | -1.7937367 | 1.4565194 |
| | 7 | -.1405172 | .40222313 | 1.000 | -1.7656453 | 1.4846108 |
| | 8 | -1.2472201 | .40222313 | .225 | -2.8723482 | .3779079 |
| | 9 | -1.2117730 | .40222313 | .255 | -2.8369011 | .4133551 |
| | 10 | -1.3546301 | .40222313 | .150 | -2.9797582 | .2704979 |
| | 11 | -1.4373922 | .40222313 | .108 | -3.0625203 | .1877358 |
| | 12 | -1.1957256 | .40222313 | .270 | -2.8208536 | .4294025 |
| | 13 | -1.2575779 | .40222313 | .217 | -2.8827059 | .3675502 |
| | 14 | -1.5905172 | .40222313 | .058 | -3.2156453 | .0346108 |

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|---|---|---|---|---|---|---|
| | 15 | -1.3393354 | .40222313 | .159 | -2.9644634 | .2857927 |
| 3 | 1 | -2.1496588(*) | .40222313 | .005 | -3.7747869 | -.5245307 |
| | 2 | -.4281320 | .40222313 | .998 | -2.0532600 | 1.1969961 |
| | 4 | -.4092742 | .40222313 | .998 | -2.0344023 | 1.2158539 |
| | 5 | -1.6123992 | .40222313 | .053 | -3.2375273 | .0127289 |
| | 6 | -.5967406 | .40222313 | .960 | -2.2218687 | 1.0283875 |
| | 7 | -.5686492 | .40222313 | .972 | -2.1937773 | 1.0564789 |
| | 8 | -1.6753521(*) | .40222313 | .040 | -3.3004802 | -.0502240 |
| | 9 | -1.6399050(*) | .40222313 | .047 | -3.2650330 | -.0147769 |
| | 10 | -1.7827621(*) | .40222313 | .026 | -3.4078902 | -.1576340 |
| | 11 | -1.8655242(*) | .40222313 | .018 | -3.4906523 | -.2403961 |
| | 12 | -1.6238575 | .40222313 | .050 | -3.2489856 | .0012705 |
| | 13 | -1.6857098 | .40222313 | .039 | -3.3108379 | -.0605818 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | (*) | | | | |
| | 14 | -2.0186492 (*) | .40222313 | .009 | -3.6437773 | -.3935211 |
| | 15 | -1.7674673 (*) | .40222313 | .027 | -3.3925954 | -.1423393 |
| 4 | 1 | -1.7403846 (*) | .40222313 | .031 | -3.3655127 | -.1152566 |
| | 2 | -.0188578 | .40222313 | 1.000 | -1.6439858 | 1.6062703 |
| | 3 | .4092742 | .40222313 | .998 | -1.2158539 | 2.0344023 |
| | 5 | -1.2031250 | .40222313 | .263 | -2.8282531 | .4220031 |
| | 6 | -.1874664 | .40222313 | 1.000 | -1.8125945 | 1.4376617 |
| | 7 | -.1593750 | .40222313 | 1.000 | -1.7845031 | 1.4657531 |
| | 8 | -1.2660779 | .40222313 | .210 | -2.8912060 | .3590502 |
| | 9 | -1.2306308 | .40222313 | .239 | -2.8557588 | .3944973 |
| | 10 | -1.3734879 | .40222313 | .140 | -2.9986160 | .2516402 |
| | 11 | -1.4562500 | .40222313 | .100 | -3.0813781 | .1688781 |
| | 12 | -1.2145833 | .40222313 | .253 | -2.8397114 | .4105447 |
| | 13 | - | .402223 | .202 | -2.9015637 | .3486924 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | 1.2764356 | 13 | | | |
| | 14 | -1.6093750 | .40222313 | .053 | -3.2345031 | .0157531 |
| | 15 | -1.3581931 | .40222313 | .148 | -2.9833212 | .2669349 |
| 5 | 1 | -.5372596 | .40222313 | .982 | -2.1623877 | 1.0878684 |
| | 2 | 1.1842672 | .40222313 | .281 | -.4408608 | 2.8093953 |
| | 3 | 1.6123992 | .40222313 | .053 | -.0127289 | 3.2375273 |
| | 4 | 1.2031250 | .40222313 | .263 | -.4220031 | 2.8282531 |
| | 6 | 1.0156586 | .40222313 | .479 | -.6094695 | 2.6407867 |
| | 7 | 1.0437500 | .40222313 | .441 | -.5813781 | 2.6688781 |
| | 8 | -.0629529 | .40222313 | 1.000 | -1.6880810 | 1.5621752 |
| | 9 | -.0275058 | .40222313 | 1.000 | -1.6526338 | 1.5976223 |
| | 10 | -.1703629 | .40222313 | 1.000 | -1.7954910 | 1.4547652 |
| | 11 | -.2531250 | .40222313 | 1.000 | -1.8782531 | 1.3720031 |
| | 12 | -.0114583 | .40222313 | 1.000 | -1.6365864 | 1.6136697 |
| | 13 | -.0733106 | .40222313 | 1.000 | -1.6984387 | 1.5518174 |
| | 14 | -.4062500 | .40222313 | .999 | -2.0313781 | 1.2188781 |

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|---|---|---|---|---|---|---|
| | 15 | -.1550681 | .40222313 | 1.000 | -1.7801962 | 1.4700599 |
| 6 | 1 | -1.5529182 | .40222313 | .068 | -3.1780463 | .0722098 |
| | 2 | .1686086 | .40222313 | 1.000 | -1.4565194 | 1.7937367 |
| | 3 | .5967406 | .40222313 | .960 | -1.0283875 | 2.2218687 |
| | 4 | .1874664 | .40222313 | 1.000 | -1.4376617 | 1.8125945 |
| | 5 | -1.0156586 | .40222313 | .479 | -2.6407867 | .6094695 |
| | 7 | .0280914 | .40222313 | 1.000 | -1.5970367 | 1.6532195 |
| | 8 | -1.0786115 | .40222313 | .397 | -2.7037396 | .5465166 |
| | 9 | -1.0431644 | .40222313 | .442 | -2.6682924 | .5819637 |
| | 10 | -1.1860215 | .40222313 | .279 | -2.8111496 | .4391066 |
| | 11 | -1.2687836 | .40222313 | .208 | -2.8939117 | .3563445 |
| | 12 | -1.0271169 | .40222313 | .463 | -2.6522450 | .5980111 |
| | 13 | -1.0889692 | .40222313 | .385 | -2.7140973 | .5361588 |
| | 14 | -1.4219086 | .40222313 | .115 | -3.0470367 | .2032195 |
| | 15 | -1.1707267 | .40222313 | .295 | -2.7958548 | .4544013 |
| 7 | 1 | - | .402223 | .060 | -3.2061377 | .0441184 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | 1.5810096 | 13 | | | |
| | 2 | .1405172 | .40222313 | 1.000 | -1.4846108 | 1.7656453 |
| | 3 | .5686492 | .40222313 | .972 | -1.0564789 | 2.1937773 |
| | 4 | .1593750 | .40222313 | 1.000 | -1.4657531 | 1.7845031 |
| | 5 | -1.0437500 | .40222313 | .441 | -2.6688781 | .5813781 |
| | 6 | -.0280914 | .40222313 | 1.000 | -1.6532195 | 1.5970367 |
| | 8 | -1.1067029 | .40222313 | .364 | -2.7318310 | .5184252 |
| | 9 | -1.0712558 | .40222313 | .407 | -2.6963838 | .5538723 |
| | 10 | -1.2141129 | .40222313 | .253 | -2.8392410 | .4110152 |
| | 11 | -1.2968750 | .40222313 | .187 | -2.9220031 | .3282531 |
| | 12 | -1.0552083 | .40222313 | .427 | -2.6803364 | .5699197 |
| | 13 | -1.1170606 | .40222313 | .352 | -2.7421887 | .5080674 |
| | 14 | -1.4500000 | .40222313 | .103 | -3.0751281 | .1751281 |
| | 15 | -1.1988181 | .40222313 | .267 | -2.8239462 | .4263099 |
| 8 | 1 | -.4743067 | .40222313 | .994 | -2.0994348 | 1.1508213 |
| | 2 | 1.2472201 | .40222313 | .225 | -.3779079 | 2.8723482 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 3 | 1.6753521 (*) | .40222313 | .040 | .0502240 | 3.3004802 |
| | 4 | 1.2660779 | .40222313 | .210 | -.3590502 | 2.8912060 |
| | 5 | .0629529 | .40222313 | 1.000 | -1.5621752 | 1.6880810 |
| | 6 | 1.0786115 | .40222313 | .397 | -.5465166 | 2.7037396 |
| | 7 | 1.1067029 | .40222313 | .364 | -.5184252 | 2.7318310 |
| | 9 | .0354471 | .40222313 | 1.000 | -1.5896809 | 1.6605752 |
| | 10 | -.1074100 | .40222313 | 1.000 | -1.7325381 | 1.5177181 |
| | 11 | -.1901721 | .40222313 | 1.000 | -1.8153002 | 1.4349560 |
| | 12 | .0514946 | .40222313 | 1.000 | -1.5736335 | 1.6766226 |
| | 13 | -.0103577 | .40222313 | 1.000 | -1.6354858 | 1.6147703 |
| | 14 | -.3432971 | .40222313 | 1.000 | -1.9684252 | 1.2818310 |
| | 15 | -.0921152 | .40222313 | 1.000 | -1.7172433 | 1.5330128 |
| 9 | 1 | -.5097539 | .40222313 | .988 | -2.1348819 | 1.1153742 |
| | 2 | 1.2117730 | .40222313 | .255 | -.4133551 | 2.8369011 |
| | 3 | 1.6399050 (*) | .40222313 | .047 | .0147769 | 3.2650330 |
| | 4 | 1.2306308 | .402223 | .239 | -.3944973 | 2.8557588 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 13 | | | |
| | 5 | .0275058 | .40222313 | 1.000 | -1.5976223 | 1.6526338 |
| | 6 | 1.0431644 | .40222313 | .442 | -.5819637 | 2.6682924 |
| | 7 | 1.0712558 | .40222313 | .407 | -.5538723 | 2.6963838 |
| | 8 | -.0354471 | .40222313 | 1.000 | -1.6605752 | 1.5896809 |
| | 10 | -.1428571 | .40222313 | 1.000 | -1.7679852 | 1.4822709 |
| | 11 | -.2256192 | .40222313 | 1.000 | -1.8507473 | 1.3995088 |
| | 12 | .0160474 | .40222313 | 1.000 | -1.6090806 | 1.6411755 |
| | 13 | -.0458049 | .40222313 | 1.000 | -1.6709329 | 1.5793232 |
| | 14 | -.3787442 | .40222313 | .999 | -2.0038723 | 1.2463838 |
| | 15 | -.1275624 | .40222313 | 1.000 | -1.7526904 | 1.4975657 |
| 10 | 1 | -.3668967 | .40222313 | .999 | -1.9920248 | 1.2582313 |
| | 2 | 1.3546301 | .40222313 | .150 | -.2704979 | 2.9797582 |
| | 3 | 1.7827621 (*) | .40222313 | .026 | .1576340 | 3.4078902 |
| | 4 | 1.3734879 | .40222313 | .140 | -.2516402 | 2.9986160 |
| | 5 | .1703629 | .40222313 | 1.000 | -1.4547652 | 1.7954910 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 6 | 1.1860215 | .40222313 | .279 | -.4391066 | 2.8111496 |
| | 7 | 1.2141129 | .40222313 | .253 | -.4110152 | 2.8392410 |
| | 8 | .1074100 | .40222313 | 1.000 | -1.5177181 | 1.7325381 |
| | 9 | .1428571 | .40222313 | 1.000 | -1.4822709 | 1.7679852 |
| | 11 | -.0827621 | .40222313 | 1.000 | -1.7078902 | 1.5423660 |
| | 12 | .1589046 | .40222313 | 1.000 | -1.4662235 | 1.7840326 |
| | 13 | .0970523 | .40222313 | 1.000 | -1.5280758 | 1.7221803 |
| | 14 | -.2358871 | .40222313 | 1.000 | -1.8610152 | 1.3892410 |
| | 15 | .0152948 | .40222313 | 1.000 | -1.6098333 | 1.6404228 |
| 11 | 1 | -.2841346 | .40222313 | 1.000 | -1.9092627 | 1.3409934 |
| | 2 | 1.4373922 | .40222313 | .108 | -.1877358 | 3.0625203 |
| | 3 | 1.8655242 (*) | .40222313 | .018 | .2403961 | 3.4906523 |
| | 4 | 1.4562500 | .40222313 | .100 | -.1688781 | 3.0813781 |
| | 5 | .2531250 | .40222313 | 1.000 | -1.3720031 | 1.8782531 |
| | 6 | 1.2687836 | .40222313 | .208 | -.3563445 | 2.8939117 |
| | 7 | 1.2968750 | .402223 | .187 | -.3282531 | 2.9220031 |

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|---|---|---|---|---|---|---|
| | | | 13 | | | |
| | 8 | .1901721 | .40222313 | 1.000 | -1.4349560 | 1.8153002 |
| | 9 | .2256192 | .40222313 | 1.000 | -1.3995088 | 1.8507473 |
| | 10 | .0827621 | .40222313 | 1.000 | -1.5423660 | 1.7078902 |
| | 12 | .2416667 | .40222313 | 1.000 | -1.3834614 | 1.8667947 |
| | 13 | .1798144 | .40222313 | 1.000 | -1.4453137 | 1.8049424 |
| | 14 | -.1531250 | .40222313 | 1.000 | -1.7782531 | 1.4720031 |
| | 15 | .0980569 | .40222313 | 1.000 | -1.5270712 | 1.7231849 |
| 12 | 1 | -.5258013 | .40222313 | .985 | -2.1509293 | 1.0993268 |
| | 2 | 1.1957256 | .40222313 | .270 | -.4294025 | 2.8208536 |
| | 3 | 1.6238575 | .40222313 | .050 | -.0012705 | 3.2489856 |
| | 4 | 1.2145833 | .40222313 | .253 | -.4105447 | 2.8397114 |
| | 5 | .0114583 | .40222313 | 1.000 | -1.6136697 | 1.6365864 |
| | 6 | 1.0271169 | .40222313 | .463 | -.5980111 | 2.6522450 |
| | 7 | 1.0552083 | .40222313 | .427 | -.5699197 | 2.6803364 |
| | 8 | -.0514946 | .40222313 | 1.000 | -1.6766226 | 1.5736335 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 9 | -.0160474 | .40222313 | 1.000 | -1.6411755 | 1.6090806 |
| | 10 | -.1589046 | .40222313 | 1.000 | -1.7840326 | 1.4662235 |
| | 11 | -.2416667 | .40222313 | 1.000 | -1.8667947 | 1.3834614 |
| | 13 | -.0618523 | .40222313 | 1.000 | -1.6869803 | 1.5632758 |
| | 14 | -.3947917 | .40222313 | .999 | -2.0199197 | 1.2303364 |
| | 15 | -.1436098 | .40222313 | 1.000 | -1.7687379 | 1.4815183 |
| 13 | 1 | -.4639490 | .40222313 | .995 | -2.0890771 | 1.1611791 |
| | 2 | 1.2575779 | .40222313 | .217 | -.3675502 | 2.8827059 |
| | 3 | 1.6857098(*) | .40222313 | .039 | .0605818 | 3.3108379 |
| | 4 | 1.2764356 | .40222313 | .202 | -.3486924 | 2.9015637 |
| | 5 | .0733106 | .40222313 | 1.000 | -1.5518174 | 1.6984387 |
| | 6 | 1.0889692 | .40222313 | .385 | -.5361588 | 2.7140973 |
| | 7 | 1.1170606 | .40222313 | .352 | -.5080674 | 2.7421887 |
| | 8 | .0103577 | .40222313 | 1.000 | -1.6147703 | 1.6354858 |
| | 9 | .0458049 | .40222313 | 1.000 | -1.5793232 | 1.6709329 |
| | 10 | -.0970523 | .402223 | 1.000 | -1.7221803 | 1.5280758 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 13 | | | |
| | 11 | -.1798144 | .40222313 | 1.000 | -1.8049424 | 1.4453137 |
| | 12 | .0618523 | .40222313 | 1.000 | -1.5632758 | 1.6869803 |
| | 14 | -.3329394 | .40222313 | 1.000 | -1.9580674 | 1.2921887 |
| | 15 | -.0817575 | .40222313 | 1.000 | -1.7068856 | 1.5433706 |
| 14 | 1 | -.1310096 | .40222313 | 1.000 | -1.7561377 | 1.4941184 |
| | 2 | 1.5905172 | .40222313 | .058 | -.0346108 | 3.2156453 |
| | 3 | 2.0186492(*) | .40222313 | .009 | .3935211 | 3.6437773 |
| | 4 | 1.6093750 | .40222313 | .053 | -.0157531 | 3.2345031 |
| | 5 | .4062500 | .40222313 | .999 | -1.2188781 | 2.0313781 |
| | 6 | 1.4219086 | .40222313 | .115 | -.2032195 | 3.0470367 |
| | 7 | 1.4500000 | .40222313 | .103 | -.1751281 | 3.0751281 |
| | 8 | .3432971 | .40222313 | 1.000 | -1.2818310 | 1.9684252 |
| | 9 | .3787442 | .40222313 | .999 | -1.2463838 | 2.0038723 |
| | 10 | .2358871 | .40222313 | 1.000 | -1.3892410 | 1.8610152 |
| | 11 | .1531250 | .40222313 | 1.000 | -1.4720031 | 1.7782531 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 12 | .3947917 | .402223 13 | .999 | -1.2303364 | 2.0199197 |
| | 13 | .3329394 | .402223 13 | 1.000 | -1.2921887 | 1.9580674 |
| | 15 | .2511819 | .402223 13 | 1.000 | -1.3739462 | 1.8763099 |
| 15 | 1 | -.3821915 | .402223 13 | .999 | -2.0073195 | 1.2429366 |
| | 2 | 1.3393354 | .402223 13 | .159 | -.2857927 | 2.9644634 |
| | 3 | 1.7674673 (*) | .402223 13 | .027 | .1423393 | 3.3925954 |
| | 4 | 1.3581931 | .402223 13 | .148 | -.2669349 | 2.9833212 |
| | 5 | .1550681 | .402223 13 | 1.000 | -1.4700599 | 1.7801962 |
| | 6 | 1.1707267 | .402223 13 | .295 | -.4544013 | 2.7958548 |
| | 7 | 1.1988181 | .402223 13 | .267 | -.4263099 | 2.8239462 |
| | 8 | .0921152 | .402223 13 | 1.000 | -1.5330128 | 1.7172433 |
| | 9 | .1275624 | .402223 13 | 1.000 | -1.4975657 | 1.7526904 |
| | 10 | -.0152948 | .402223 13 | 1.000 | -1.6404228 | 1.6098333 |
| | 11 | -.0980569 | .402223 13 | 1.000 | -1.7231849 | 1.5270712 |
| | 12 | .1436098 | .402223 13 | 1.000 | -1.4815183 | 1.7687379 |
| | 13 | .0817575 | .402223 | 1.000 | -1.5433706 | 1.7068856 |

| | | | | | |
|---|---|---|---|---|---|
| 14 | -.2511819 | .402223 13 13 | 1.000 | -1.8763099 | 1.3739462 |

Based on observed means.

* The mean difference is significant at the .05 level.

**APPENDIX 5**

**SPSS analysis of the results at 11 Weeks After Planting (WAP)**

**Tests of Between-Subjects Effects**

Dependent Variable: avg score

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 16.925(a) | 15 | 1.128 | 11.848 | .000 |
| Intercept | 89.440 | 1 | 89.440 | 939.133 | .000 |
| Treatment | 16.912 | 14 | 1.208 | 12.684 | .000 |
| Block | .013 | 1 | .013 | .135 | .719 |
| Error | 1.333 | 14 | .095 | | |
| Total | 107.698 | 30 | | | |
| Corrected Total | 18.258 | 29 | | | |

a R Squared = .927 (Adjusted R Squared = .849)

**Post Hoc Tests**

**Treatment**

**Multiple Comparisons**

Dependent Variable: avg score

Tukey HSD

| | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| (I) treatment | (J) treatment | Lower Bound | Upper Bound | Lower Bound | Upper Bound | Lower Bound |
| 1 | 2 | 2.0113147 (*) | .30860471 | .001 | .7644391 | 3.2581902 |
| | 3 | 2.3333333 (*) | .30860471 | .000 | 1.0864578 | 3.5802089 |
| | 4 | 2.1093750 (*) | .30860471 | .000 | .8624995 | 3.3562505 |
| | 5 | .1718750 | .30860471 | 1.000 | -1.0750005 | 1.4187505 |
| | 6 | 1.3959341 (*) | .30860471 | .022 | .1490586 | 2.6428097 |
| | 7 | 1.4722782 (*) | .30860471 | .014 | .2254027 | 2.7191538 |
| | 8 | .7778935 | .30860471 | .481 | -.4689820 | 2.0247690 |
| | 9 | .5334821 | .30860471 | .892 | -.7133934 | 1.7803577 |
| | 10 | .0574597 | .30860471 | 1.000 | -1.1894158 | 1.3043352 |
| | 11 | .3864583 | .30860471 | .989 | -.8604172 | 1.6333339 |
| | 12 | .6108871 | .30860471 | .782 | -.6359884 | 1.8577626 |
| | 13 | .5271169 | .30860471 | .899 | -.7197586 | 1.7739925 |
| | 14 | .4531250 | .308604 | .962 | -.7937505 | 1.7000005 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 71 | | | |
| | 15 | .4002736 | .30860471 | .986 | -.8466019 | 1.6471491 |
| 2 | 1 | -2.0113147(*) | .30860471 | .001 | -3.2581902 | -.7644391 |
| | 3 | .3220187 | .30860471 | .998 | -.9248568 | 1.5688942 |
| | 4 | .0980603 | .30860471 | 1.000 | -1.1488152 | 1.3449359 |
| | 5 | -1.8394397(*) | .30860471 | .002 | -3.0863152 | -.5925641 |
| | 6 | -.6153805 | .30860471 | .774 | -1.8622560 | .6314950 |
| | 7 | -.5390364 | .30860471 | .885 | -1.7859120 | .7078391 |
| | 8 | -1.2334211 | .30860471 | .054 | -2.4802967 | .0134544 |
| | 9 | -1.4778325(*) | .30860471 | .014 | -2.7247080 | -.2309570 |
| | 10 | -1.9538550(*) | .30860471 | .001 | -3.2007305 | -.7069795 |
| | 11 | -1.6248563(*) | .30860471 | .006 | -2.8717318 | -.3779808 |
| | 12 | -1.4004276(*) | .30860471 | .021 | -2.6473031 | -.1535520 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 13 | -1.4841977(*) | .30860471 | .013 | -2.7310732 | -.2373222 |
| | 14 | -1.5581897(*) | .30860471 | .009 | -2.8050652 | -.3113141 |
| | 15 | -1.6110410(*) | .30860471 | .007 | -2.8579166 | -.3641655 |
| 3 | 1 | -2.3333333(*) | .30860471 | .000 | -3.5802089 | -1.0864578 |
| | 2 | -.3220187 | .30860471 | .998 | -1.5688942 | .9248568 |
| | 4 | -.2239583 | .30860471 | 1.000 | -1.4708339 | 1.0229172 |
| | 5 | -2.1614583(*) | .30860471 | .000 | -3.4083339 | -.9145828 |
| | 6 | -.9373992 | .30860471 | .246 | -2.1842747 | .3094763 |
| | 7 | -.8610551 | .30860471 | .346 | -2.1079306 | .3858204 |
| | 8 | -1.5554398(*) | .30860471 | .009 | -2.8023153 | -.3085643 |
| | 9 | -1.7998512(*) | .30860471 | .002 | -3.0467267 | -.5529757 |
| | 10 | -2.2758737 | .30860471 | .000 | -3.5227492 | -1.0289981 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | (*) | | | | |
| | 11 | -1.9468750(*) | .30860471 | .001 | -3.1937505 | -.6999995 |
| | 12 | -1.7224462(*) | .30860471 | .004 | -2.9693218 | -.4755707 |
| | 13 | -1.8062164(*) | .30860471 | .002 | -3.0530919 | -.5593409 |
| | 14 | -1.8802083(*) | .30860471 | .002 | -3.1270839 | -.6333328 |
| | 15 | -1.9330597(*) | .30860471 | .001 | -3.1799352 | -.6861842 |
| 4 | 1 | -2.1093750(*) | .30860471 | .000 | -3.3562505 | -.8624995 |
| | 2 | -.0980603 | .30860471 | 1.000 | -1.3449359 | 1.1488152 |
| | 3 | .2239583 | .30860471 | 1.000 | -1.0229172 | 1.4708339 |
| | 5 | -1.9375000(*) | .30860471 | .001 | -3.1843755 | -.6906245 |
| | 6 | -.7134409 | .30860471 | .598 | -1.9603164 | .5334347 |
| | 7 | -.6370968 | .30860471 | .737 | -1.8839723 | .6097788 |
| | 8 | - | .308604 | .031 | -2.5783570 | -.0846060 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | 1.3314815(*) | 71 | | | |
| | 9 | -1.5758929(*) | .30860471 | .008 | -2.8227684 | -.3290173 |
| | 10 | -2.0519153(*) | .30860471 | .001 | -3.2987908 | -.8050398 |
| | 11 | -1.7229167(*) | .30860471 | .004 | -2.9697922 | -.4760411 |
| | 12 | -1.4984879(*) | .30860471 | .012 | -2.7453634 | -.2516124 |
| | 13 | -1.5822581(*) | .30860471 | .008 | -2.8291336 | -.3353825 |
| | 14 | -1.6562500(*) | .30860471 | .005 | -2.9031255 | -.4093745 |
| | 15 | -1.7091014(*) | .30860471 | .004 | -2.9559769 | -.4622259 |
| 5 | 1 | -.1718750 | .30860471 | 1.000 | -1.4187505 | 1.0750005 |
| | 2 | 1.8394397(*) | .30860471 | .002 | .5925641 | 3.0863152 |
| | 3 | 2.1614583(*) | .30860471 | .000 | .9145828 | 3.4083339 |
| | 4 | 1.9375000(*) | .30860471 | .001 | .6906245 | 3.1843755 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 6 | 1.2240591 | .30860471 | .057 | -.0228164 | 2.4709347 |
| | 7 | 1.3004032(*) | .30860471 | .037 | .0535277 | 2.5472788 |
| | 8 | .6060185 | .30860471 | .790 | -.6408570 | 1.8528940 |
| | 9 | .3616071 | .30860471 | .994 | -.8852684 | 1.6084827 |
| | 10 | -.1144153 | .30860471 | 1.000 | -1.3612908 | 1.1324602 |
| | 11 | .2145833 | .30860471 | 1.000 | -1.0322922 | 1.4614589 |
| | 12 | .4390121 | .30860471 | .970 | -.8078634 | 1.6858876 |
| | 13 | .3552419 | .30860471 | .995 | -.8916336 | 1.6021175 |
| | 14 | .2812500 | .30860471 | .999 | -.9656255 | 1.5281255 |
| | 15 | .2283986 | .30860471 | 1.000 | -1.0184769 | 1.4752741 |
| 6 | 1 | -1.3959341(*) | .30860471 | .022 | -2.6428097 | -.1490586 |
| | 2 | .6153805 | .30860471 | .774 | -.6314950 | 1.8622560 |
| | 3 | .9373992 | .30860471 | .246 | -.3094763 | 2.1842747 |
| | 4 | .7134409 | .30860471 | .598 | -.5334347 | 1.9603164 |
| | 5 | -1.2240591 | .30860471 | .057 | -2.4709347 | .0228164 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 7 | .0763441 | .30860471 | 1.000 | -1.1705314 | 1.3232196 |
| | 8 | -.6180406 | .30860471 | .770 | -1.8649161 | .6288349 |
| | 9 | -.8624520 | .30860471 | .344 | -2.1093275 | .3844235 |
| | 10 | -1.3384745(*) | .30860471 | .030 | -2.5853500 | -.0915989 |
| | 11 | -1.0094758 | .30860471 | .174 | -2.2563513 | .2373997 |
| | 12 | -.7850470 | .30860471 | .468 | -2.0319226 | .4618285 |
| | 13 | -.8688172 | .30860471 | .335 | -2.1156927 | .3780583 |
| | 14 | -.9428091 | .30860471 | .240 | -2.1896847 | .3040664 |
| | 15 | -.9956605 | .30860471 | .187 | -2.2425360 | .2512150 |
| 7 | 1 | -1.4722782(*) | .30860471 | .014 | -2.7191538 | -.2254027 |
| | 2 | .5390364 | .30860471 | .885 | -.7078391 | 1.7859120 |
| | 3 | .8610551 | .30860471 | .346 | -.3858204 | 2.1079306 |
| | 4 | .6370968 | .30860471 | .737 | -.6097788 | 1.8839723 |
| | 5 | -1.3004032(*) | .30860471 | .037 | -2.5472788 | -.0535277 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 6 | -.0763441 | .30860471 | 1.000 | -1.3232196 | 1.1705314 |
| | 8 | -.6943847 | .30860471 | .634 | -1.9412602 | .5524908 |
| | 9 | -.9387961 | .30860471 | .245 | -2.1856716 | .3080794 |
| | 10 | -1.4148185(*) | .30860471 | .020 | -2.6616941 | -.1679430 |
| | 11 | -1.0858199 | .30860471 | .118 | -2.3326954 | .1610556 |
| | 12 | -.8613911 | .30860471 | .346 | -2.1082667 | .3854844 |
| | 13 | -.9451613 | .30860471 | .238 | -2.1920368 | .3017142 |
| | 14 | -1.0191532 | .30860471 | .166 | -2.2660288 | .2277223 |
| | 15 | -1.0720046 | .30860471 | .127 | -2.3188801 | .1748709 |
| 8 | 1 | -.7778935 | .30860471 | .481 | -2.0247690 | .4689820 |
| | 2 | 1.2334211 | .30860471 | .054 | -.0134544 | 2.4802967 |
| | 3 | 1.5554398(*) | .30860471 | .009 | .3085643 | 2.8023153 |
| | 4 | 1.3314815(*) | .30860471 | .031 | .0846060 | 2.5783570 |
| | 5 | -.6060185 | .30860471 | .790 | -1.8528940 | .6408570 |
| | 6 | .6180406 | .30860471 | .770 | -.6288349 | 1.8649161 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 7 | .6943847 | .30860471 | .634 | -.5524908 | 1.9412602 |
| | 9 | -.2444114 | .30860471 | 1.000 | -1.4912869 | 1.0024641 |
| | 10 | -.7204338 | .30860471 | .585 | -1.9673094 | .5264417 |
| | 11 | -.3914352 | .30860471 | .988 | -1.6383107 | .8554403 |
| | 12 | -.1670064 | .30860471 | 1.000 | -1.4138819 | 1.0798691 |
| | 13 | -.2507766 | .30860471 | 1.000 | -1.4976521 | .9960989 |
| | 14 | -.3247685 | .30860471 | .998 | -1.5716440 | .9221070 |
| | 15 | -.3776199 | .30860471 | .991 | -1.6244954 | .8692556 |
| 9 | 1 | -.5334821 | .30860471 | .892 | -1.7803577 | .7133934 |
| | 2 | 1.4778325 (*) | .30860471 | .014 | .2309570 | 2.7247080 |
| | 3 | 1.7998512 (*) | .30860471 | .002 | .5529757 | 3.0467267 |
| | 4 | 1.5758929 (*) | .30860471 | .008 | .3290173 | 2.8227684 |
| | 5 | -.3616071 | .30860471 | .994 | -1.6084827 | .8852684 |
| | 6 | .8624520 | .30860471 | .344 | -.3844235 | 2.1093275 |
| | 7 | .9387961 | .30860471 | .245 | -.3080794 | 2.1856716 |
| | 8 | .2444114 | .308604 | 1.000 | -1.0024641 | 1.4912869 |

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|---|---|---|---|---|---|---|
| | | | 71 | | | |
| | 10 | -.4760225 | .30860471 | .947 | -1.7228980 | .7708531 |
| | 11 | -.1470238 | .30860471 | 1.000 | -1.3938993 | 1.0998517 |
| | 12 | .0774050 | .30860471 | 1.000 | -1.1694706 | 1.3242805 |
| | 13 | -.0063652 | .30860471 | 1.000 | -1.2532407 | 1.2405103 |
| | 14 | -.0803571 | .30860471 | 1.000 | -1.3272327 | 1.1665184 |
| | 15 | -.1332085 | .30860471 | 1.000 | -1.3800841 | 1.1136670 |
| 10 | 1 | -.0574597 | .30860471 | 1.000 | -1.3043352 | 1.1894158 |
| | 2 | 1.9538550(*) | .30860471 | .001 | .7069795 | 3.2007305 |
| | 3 | 2.2758737(*) | .30860471 | .000 | 1.0289981 | 3.5227492 |
| | 4 | 2.0519153(*) | .30860471 | .001 | .8050398 | 3.2987908 |
| | 5 | .1144153 | .30860471 | 1.000 | -1.1324602 | 1.3612908 |
| | 6 | 1.3384745(*) | .30860471 | .030 | .0915989 | 2.5853500 |
| | 7 | 1.4148185(*) | .30860471 | .020 | .1679430 | 2.6616941 |
| | 8 | .7204338 | .30860471 | .585 | -.5264417 | 1.9673094 |
| | 9 | .4760225 | .30860471 | .947 | -.7708531 | 1.7228980 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 11 | .3289987 | .30860471 | .997 | -.9178769 | 1.5758742 |
| | 12 | .5534274 | .30860471 | .867 | -.6934481 | 1.8003029 |
| | 13 | .4696573 | .30860471 | .952 | -.7772183 | 1.7165328 |
| | 14 | .3956653 | .30860471 | .987 | -.8512102 | 1.6425408 |
| | 15 | .3428139 | .30860471 | .996 | -.9040616 | 1.5896895 |
| 11 | 1 | -.3864583 | .30860471 | .989 | -1.6333339 | .8604172 |
| | 2 | 1.6248563(*) | .30860471 | .006 | .3779808 | 2.8717318 |
| | 3 | 1.9468750(*) | .30860471 | .001 | .6999995 | 3.1937505 |
| | 4 | 1.7229167(*) | .30860471 | .004 | .4760411 | 2.9697922 |
| | 5 | -.2145833 | .30860471 | 1.000 | -1.4614589 | 1.0322922 |
| | 6 | 1.0094758 | .30860471 | .174 | -.2373997 | 2.2563513 |
| | 7 | 1.0858199 | .30860471 | .118 | -.1610556 | 2.3326954 |
| | 8 | .3914352 | .30860471 | .988 | -.8554403 | 1.6383107 |
| | 9 | .1470238 | .30860471 | 1.000 | -1.0998517 | 1.3938993 |
| | 10 | -.3289987 | .30860471 | .997 | -1.5758742 | .9178769 |
| | 12 | .2244288 | .308604 | 1.000 | -1.0224468 | 1.4713043 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 71 | | | |
| | 13 | .1406586 | .30860471 | 1.000 | -1.1062169 | 1.3875341 |
| | 14 | .0666667 | .30860471 | 1.000 | -1.1802089 | 1.3135422 |
| | 15 | .0138153 | .30860471 | 1.000 | -1.2330602 | 1.2606908 |
| 12 | 1 | -.6108871 | .30860471 | .782 | -1.8577626 | .6359884 |
| | 2 | 1.4004276(*) | .30860471 | .021 | .1535520 | 2.6473031 |
| | 3 | 1.7224462(*) | .30860471 | .004 | .4755707 | 2.9693218 |
| | 4 | 1.4984879(*) | .30860471 | .012 | .2516124 | 2.7453634 |
| | 5 | -.4390121 | .30860471 | .970 | -1.6858876 | .8078634 |
| | 6 | .7850470 | .30860471 | .468 | -.4618285 | 2.0319226 |
| | 7 | .8613911 | .30860471 | .346 | -.3854844 | 2.1082667 |
| | 8 | .1670064 | .30860471 | 1.000 | -1.0798691 | 1.4138819 |
| | 9 | -.0774050 | .30860471 | 1.000 | -1.3242805 | 1.1694706 |
| | 10 | -.5534274 | .30860471 | .867 | -1.8003029 | .6934481 |
| | 11 | -.2244288 | .30860471 | 1.000 | -1.4713043 | 1.0224468 |
| | 13 | -.0837702 | .30860471 | 1.000 | -1.3306457 | 1.1631054 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 14 | -.1577621 | .30860471 | 1.000 | -1.4046376 | 1.0891134 |
| | 15 | -.2106135 | .30860471 | 1.000 | -1.4574890 | 1.0362620 |
| 13 | 1 | -.5271169 | .30860471 | .899 | -1.7739925 | .7197586 |
| | 2 | 1.4841977(*) | .30860471 | .013 | .2373222 | 2.7310732 |
| | 3 | 1.8062164(*) | .30860471 | .002 | .5593409 | 3.0530919 |
| | 4 | 1.5822581(*) | .30860471 | .008 | .3353825 | 2.8291336 |
| | 5 | -.3552419 | .30860471 | .995 | -1.6021175 | .8916336 |
| | 6 | .8688172 | .30860471 | .335 | -.3780583 | 2.1156927 |
| | 7 | .9451613 | .30860471 | .238 | -.3017142 | 2.1920368 |
| | 8 | .2507766 | .30860471 | 1.000 | -.9960989 | 1.4976521 |
| | 9 | .0063652 | .30860471 | 1.000 | -1.2405103 | 1.2532407 |
| | 10 | -.4696573 | .30860471 | .952 | -1.7165328 | .7772183 |
| | 11 | -.1406586 | .30860471 | 1.000 | -1.3875341 | 1.1062169 |
| | 12 | .0837702 | .30860471 | 1.000 | -1.1631054 | 1.3306457 |
| | 14 | -.0739919 | .30860471 | 1.000 | -1.3208675 | 1.1728836 |
| | 15 | -.1268433 | .308604 | 1.000 | -1.3737188 | 1.1200322 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 71 | | | |
| 14 | 1 | -.4531250 | .30860471 | .962 | -1.7000005 | .7937505 |
| | 2 | 1.5581897 (*) | .30860471 | .009 | .3113141 | 2.8050652 |
| | 3 | 1.8802083 (*) | .30860471 | .002 | .6333328 | 3.1270839 |
| | 4 | 1.6562500 (*) | .30860471 | .005 | .4093745 | 2.9031255 |
| | 5 | -.2812500 | .30860471 | .999 | -1.5281255 | .9656255 |
| | 6 | .9428091 | .30860471 | .240 | -.3040664 | 2.1896847 |
| | 7 | 1.0191532 | .30860471 | .166 | -.2277223 | 2.2660288 |
| | 8 | .3247685 | .30860471 | .998 | -.9221070 | 1.5716440 |
| | 9 | .0803571 | .30860471 | 1.000 | -1.1665184 | 1.3272327 |
| | 10 | -.3956653 | .30860471 | .987 | -1.6425408 | .8512102 |
| | 11 | -.0666667 | .30860471 | 1.000 | -1.3135422 | 1.1802089 |
| | 12 | .1577621 | .30860471 | 1.000 | -1.0891134 | 1.4046376 |
| | 13 | .0739919 | .30860471 | 1.000 | -1.1728836 | 1.3208675 |
| | 15 | -.0528514 | .30860471 | 1.000 | -1.2997269 | 1.1940241 |
| 15 | 1 | -.4002736 | .30860471 | .986 | -1.6471491 | .8466019 |

| | | | | | |
|---|---|---|---|---|---|
| 2 | 1.6110410 (*) | .30860471 | .007 | .3641655 | 2.8579166 |
| 3 | 1.9330597 (*) | .30860471 | .001 | .6861842 | 3.1799352 |
| 4 | 1.7091014 (*) | .30860471 | .004 | .4622259 | 2.9559769 |
| 5 | -.2283986 | .30860471 | 1.000 | -1.4752741 | 1.0184769 |
| 6 | .9956605 | .30860471 | .187 | -.2512150 | 2.2425360 |
| 7 | 1.0720046 | .30860471 | .127 | -.1748709 | 2.3188801 |
| 8 | .3776199 | .30860471 | .991 | -.8692556 | 1.6244954 |
| 9 | .1332085 | .30860471 | 1.000 | -1.1136670 | 1.3800841 |
| 10 | -.3428139 | .30860471 | .996 | -1.5896895 | .9040616 |
| 11 | -.0138153 | .30860471 | 1.000 | -1.2606908 | 1.2330602 |
| 12 | .2106135 | .30860471 | 1.000 | -1.0362620 | 1.4574890 |
| 13 | .1268433 | .30860471 | 1.000 | -1.1200322 | 1.3737188 |
| 14 | .0528514 | .30860471 | 1.000 | -1.1940241 | 1.2997269 |

Based on observed means.* The mean difference is significant at the .05 level.