Performance of wild watermelon (*Citrullus lanatus* L.) in response to population density and mulch

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DECLARATION

I, Noxolo P. Mtumtum, hereby declare that this dissertation is the result of my own original work unless where specifically indicated and acknowledgement is made to the work of others.

Signature : ……………………….

Noxolo P. Mtumtum

I agree with the above statement

Supervisor: ……………………….

Professor Albert T. Modi

DEDICATION

This work is dedicated to my late father, Nkohla Hilton Mtumtum and my mother, Philda Nzimakazi Mtumtum for her relentless effort to have us educated as my father died at our tender ages.

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ABSTRACT

The wild watermelon, *Citrullus lanatus* L. was among the most important foodstuffs to a number of African communities, until the colonists introduced their own foodstuffs in a process that was highly supported by the laws of the time. However, there is now a growing realization by government and other stakeholders of the importance of indigenous crops (including the wild watermelon) as substitute food stuff to improve food security. Wild watermelon is an adaptable crop, which can contribute to food security as it has a potential for commercialization. However, there are no records on the production of wild watermelon with reference to optimum planting density and the effects of mulch on the growth and development of the crop.

To investigate this issue, which the smallholder farmers are faced with, a study that designed to (a) determine the effects of population density on growth and yield of wild watermelon and (b) investigate the effects of mulching on growth and yield of wild watermelon under field conditions. The study was undertaken over two seasons during which two different types of propagules, namely seed and seedlings, were used. A field study of wild watermelon establishment and yield using seeds and seedlings to compare the effects of different population densities (3000, 6000, 9000 and 12000 plants/ha) and mulching rates (0, 2.5 and 5 t/ha) based on the availability of grass on soil water, temperature, vine length (height), number of branches and leaves per plant, fruit number, total yields, fruit size and weed distribution was conducted at Dohne Agricultural Development Institute (Lat-32.52521; Long – 27.46119, alt. 907 m above sea-level) over a two year period (2009 – 2011 growing season). Results on data collection and analysis of growth and yield parameters are that:

When seed was used as means of propagation, there were significant effects ($p \leq 0.05$) of mulching and population density, on soil temperature and volumetric water content. However, no significant differences were found with regards to vine length, number of branches and leaves per plant. Concerning yield, there were no significant differences recorded on any of the measured parameters in response to mulch. Yet, with population density, significant differences were noted on fruit number per hectare and total yield at $p \leq 0.05$. The number of fruits and total yield per hectare increased as plant population increased, resulting in high yields to range from 9000 -12 000 plants per hectare with both seed and seedling propagules used during the study period with or without mulching.

Seedling propagules were associated with differences in soil temperature and volumetric water content with regards to mulching and population density ($p \leq 0.05$). Results obtained from this study in both years, revealed that yield is more influenced by plant population density than by mulching. Mulching has been found to be ineffective as far as growth and yield are concerned, but it was found to influence soil temperature and volumetric water content.

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LITERATURE REVIEW

1.1 Introduction

Indigenous watermelon (*Citrullus lanatus*) was among the most important foodstuffs consumed by Africans when they lived nomadic lifestyle of moving from one place to another (Bhat and Rubuluza, 2002). During that time, the period between moving from one place to another was determined by availability of food as their survival depended on hunting and gathering food from the wild. Apart from gathering food, they used to plant wild seeds from gathered foodstuffs (Sobahle, 1982). According to Sobahle (1982), crops that were mostly grown by the Nguni tribes, especially the Xhosas, were kaffircorn/millet, pumpkins, wild watermelon, kidney beans and sweet sorghum. The wild seeds including wild watermelon were planted on fertile soils which were normally along the river valleys. The land preparation of these soils was through the slash and burn method. Once land was exhausted, Nomads would then shift and plant their crops to a more fertile land (Mkile, 2001).

The cropping system practised was intercropping, which is defined by Andrews and Kassam (1976) and Ncube (2003) as the growing of different crops simultaneously on the same piece of land. Intercropping increased yields per unit area Mhlontlo (2008) citing Mukhala et al., (1999).Wild melons and pumpkins were used as minor crops in maize fields and acted as live-mulch by covering the soil surface, thereby controlling weeds. Moreover, food availability improved through intercropping due to the minor crop's early maturity (February to end March), which together with green mealies were harvested and consumed as they became available (Sobahle, 1982).

The nomadic life style was practised until the arrival of the colonists in 1652 (Simon and Lamla, 1991; Modi, 2003). After colonization, traditional or indigenous food crops became less attractive as the colonists were introducing their foodstuffs and the process was supported by laws such as land tenure where people were neither allowed to hunt nor gather food (Alphane, 2002). The promotion of exotic crops which was backed up by western scientific research and development, led to the decline in cultivation, consumption and ultimately the loss of indigenous food crops, despite centuries of their survival mechanisms in the environment (Norman et al.1996; Alphane et al. 2003).

Indigenous crops, including vegetables, grains and fruits, played a significant role in the early history of South Africa as a source of food, not only for indigenous people, but also for colonists that lived in the Cape in the 1600s (Modi, 2003). These indigenous food crops have a strategic food security role in offering important opportunities for the poor, particularly women, through farming, processing and trading activities (Schippers, 2000). Apart from their early history, even these days indigenous crops still play an important role in the lives of rural communities as sources of food (Mhlontlo, 2008).To enhance economic activity and global competitiveness of subsistence farmers, more research and documentation on indigenous food crops need to be established (Modi, 2003).

Indigenous watermelon is termed as a unique plant of South African deserts because of its sustenance of many inhabitants during waterless times (Anomymous, 2008 citing Livingstone, 1857). According to Zulu and Modi (2010), melons have been an important source of water and food for indigenous people, travellers and also for livestock. It is an easy to grow food source with the potential for commercialization. Moreover, melons have been found to reduce frequency of weeding and production costs by acting as live mulch when grown as minor crop in maize fields (Silwana, 2000; Schippers, 2000; Vorster et al. 2002). Weeds, within the context of food production are plants that interfere with cultivation activity or in some way hamper human welfare and are of major economic importance in crop production world-wide (Akobundu, 1987; Kostov and Pacanoski, 2007). Records of 5%, 10% and 25% yield differences in losses due to weeds in most, less and least developed countries respectively had been reported in agricultural production by Vissoh, *et al.*, (2004) citing Akobundu, (1987).Yield losses due to poor weed management cause extensive financial losses in crop production. Yakubu and Karaye, (2006), reported onion bulb yield losses of about 79-89%;100% in muskmelon and watermelon by Chiduza *et al.,* 2010 citing Terry *et al.*, 1997; 20-30% in butternut by Chiduza *et al.*, 2010; 10% in watermelon by Berry *et al.*, (2006). In view of the above findings, it is clear that direct losses caused by weeds vary from crop to crop and their control is of economic importance. Amaranthus as one of edible leafy vegetable had a potential to co-exist with watermelon. In the

Eastern Cape, farmers gather their leaves from the wild, chop and mix with maize meal to prepare a traditional meal known as '*imifino* or *isigwampa*.' When cooked as '*imifino*', the indigenous leafy vegetables would supplement the necessary proteins, minerals and vitamins that maize is a poor source of. When compared to spinach, Amaranthus contains three times more vitamin C, iron, calcium and niacin whilst with lettuce; it has eighteen times more vitamin A, twenty times more calcium and seven times more iron (Mhlontlo, 2008, citing Mnkeni, 2005; Makus, 1984). This explains why one person's devastating weed in time and place may be another person's valuable plant.

Wild watermelon is an important crop grown by small-holder farmers in the Eastern Cape. In order for farmers to realize great returns from the crop, any limiting factors such as weeds have to be dealt with as it would result in economic losses of 10% (Berry *et al.*, 2006). The choice of any weed management strategy will depend on the type of farming system practiced as well as availability of materials to be used hence mulch using *Panicum maximum* Jacq. at different rates was used.

Mulching (dead or live) is a crop production technique that involves planting or placement of organic or inorganic materials on the soil surface to provide a more favorable environment for plant growth and development (Aguyoh et al. 2006). Mulches can alter soil temperature and moisture condition which may affect crop growth and development and ultimately yields (Aguyoh et al. 2006; Ramakrishma et al. 2006; Debashis et al. 2008). Use of plastic mulches (inorganic materials) has been documented with melons quite extensively with profits, but there are no reports on organic mulching of melons. There is a need to also examine the response of wild watermelons towards organic mulch for development of appropriate technical advisory packages.

There is now a growing realization by government and other role players in South Africa of the importance of indigenous crops as alternative food crops to enhance food security and biodiversity (Draft Policy on Indigenous Food Crops (DPIFC), 6th draft). As a result of changes in government policy, agronomic research has been started on some of indigenous crops such as *Amaranthus spp.* (Mnkeni 2005; Mhlontlo, 2008) while studies by Modi (2007) dealt much with seed technology of wild melon. Determination of the lowest plant population necessary for optimal yield as a major agronomic goal has been done for many crops such as muskmelon, cucumbers, squash, melon and watermelon (Duthie et al. 1999). No records were found on the production of indigenous watermelon with reference to optimum planting density and effects of mulch on growth and its development.

1.2 Origin and food value of watermelon

Wild watermelon originated in Kalahari Desert, South Africa and Sahara desert in Africa where it can still be found in the wild in a diversity of forms together with other *Citrullus* species (Schippers 2002, Van der Vossen et al. 2004). Thus, it is an indigenous crop of South Africa and is also widely distributed in tropics, subtropics and warm temperate zones of the world (Dauda et al. 2008 citing Jarret et al., 1996; Victor, 2005; Botha 2005, Van der Vossen et al. 2004 and Anomymous, 2008). *Citrullus lanatus* is rated first among the four that are of economic importance (Pitrat *et al*., 1999) as it is directly (subsistence purposes) and indirectly (industrial purposes) used by small-holder farmers.

1.2.1 Subsistence purposes

Wild watermelon as an edible species is used in different forms such that its leaves, flowers and the young fruit are cooked as green vegetables (Schippers, 2000; Fox and Norwood Young, 1982; Van Wyk and Gericke, 2000 cited by Jansen van Rensburg, et al. 2007). The matured fruit is an economic portion of cucurbits cultivated widely within the smallholder traditional food crop production systems in South Africa. The fruit features prominently in the diet of smallholder farmers of the Eastern Cape where upon cooking it is mixed with maize meal, maize or mielie rice to a form traditional dish that is stiff porridge (umqa in Xhosa), when mixed with fresh maize it is known as '*umxhaxha*'. It is used to a lesser extent in making jam. The fruit varies in size, shape and colour (Fox and Young, 1982 cited by Jansen van Rensburg, 2007. It can be a source of income as small-holder farmers do sell to each other. The cucurbits in general are classified according to size by weight from smallest to the largest with the fruit size being the price determinant (Bratsch, 2006) and of relevance to yield including the fruit number per plant and hectare (Olufemi et al., 2006).

In the Kalahari Desert in Southern Africa, wild watermelon (known as tsamma melon) is used as an important source of both food and water in times of drought (Jansen van Rensburg et al. 2007; Anomymous, 2008).

Pumpkins and melons in South Africa are often intercropped with maize, which helps to control weeds (Silwana, 2000, Schippers, 2000; Jansen van Rensburg et al. 2007). It can be planted as a relay crop in sorghum fields as it is more drought tolerant (Schippers, 2002; Anomymous, 2008).

1.2.2 Industrial use

As fruit is of economic importance in South Africa, in other parts of Africa such as Nigeria, Senegal, etc. the seed is of economic importance**.** The seed is rich in fats and proteins. It is widely eaten as a snack, added to other dishes or used as an oilseed (Schippers, 2000; Anomymous, 2008; Victor, 2005 citing van Wyk and Gericke, 2000; Jansen van Rensburg et al. 2007 citing Fox and Norwood Young, 1982). Van de Vossen et al. (2004) reported that oil extracted from the seed has various uses namely, domestic uses (cooking as well as salad dressing) and pharmaceutical uses (e.g. cosmetics). The seed cake after oil extraction can be used as a livestock feed (Anonymous, 2008).

Wild watermelons, known as citron or preserving melon, are used exclusively for processing. When processed, it is used for pickling and preservatives. Because of its high pectin content, the fruit is a popular constituent of jams and jellies (van Wyk and Gericke, 2000). It is also added to juices to make them gel more rapidly (Anomymous, 2008).

Wild watermelon can contribute to food security as it has a potential for commercialization (Zulu and Modi, 2010). It is also a reliable source of food and water for people, domestic and wild animals with a shelf life of more than a year (Anomymous, 2008). Moreover, wild watermelon has proven to be a versatile crop due to its multi-purpose nature as it is used by people as well as livestock and the fact that it can withstand various environmental conditions. In the context of climate change, water melon is crucial to food security now due to its uniquely drought resistant nature as an alternative crop that can withstand high temperatures.

1.3 Botany

The indigenous watermelon belongs to the family, *Cucurbitaceae,* which is a large family found in the warmer parts of all continents. *Cucurbitaceae* consist of 115 – 118 genera with about 825 edible species. Among the 115 to118 genera, *Citrullus* (watermelon), *Cucurbita* (pumpkins and squashes), *Cucumis* (melons) and *Langenaria* (bottle gourd/calabash) are the four genera that are of great economic importance (Schippers, 2002; Pitrat et al. 1999; Jansen van Rensburg et al. 2007). *Citrullus lanatus* (indigenous watermelon) is a trailing annual, herbaceous plant with hairy stems, forked tendrils and three lobed hairy leaves. The wild watermelon has pinnately lobed leaves that distinguish it from the other cucurbits such as melon, pumpkin, squash, etc. (Anomymous, 2008). The male and female flowers are born on the same plant (monoecious) (Jansen van Rensburg et al. 2007). The male flowers are pale yellow and staminate while female flowers are brightly yellow. The fruit as a berry is globose to oblong or ellipsoid greenish, mottled with dark green, pale green or grayish green with or without stripes. The fruit's flesh which is made up of mesocarp and endocarp varies from pale green to yellow (Victor, 2005). The seeds may be rarely white, yellow, red, black, and brown in colour (Anomymous, 2008; Zulu, 2010; Van der Vossen et al. 2004).

Indigenous watermelon is a dicotyledonous plant that carries on photosynthesis by C3 carbon fixation pathway in which the first photosynthesis product is a three carbon compound (Botha, 2005). The characteristic is also available in many other well-known C4 crops sorghum, wheat etc. Wild watermelon is considered as the more drought tolerant than most melons because of its deep root system making it easy for the crop to thrive well in arid areas with as little water as 250 mm per season (Schippers, (2002); Botha, (2005); Victor, (2005) and Anonymous, 2008). Reports by Schippers, (2002); Botha, (2005); Victor, (2005) and Anonymous, (2008) are further expanded by Yoshimura *et al.*, 2008 who suggests that this drought tolerant characteristic is due to enhancement of root growth or root morphogenesis.

1.4. Agronomy

1.4.1 Climatic requirements

Watermelon is a warm-temperate crop that requires a relatively long, hot growing season of four months (120 to 130 days) and frost free weather (Coertze, 1996; Smith, 2006; Anomymous, 2008). Botha (2005) reported that it requires temperatures of 20°C to 30°C with optimal fruit development temperature of 30°C to 35°C. An annual rainfall of about 600 mm to 1200 mm is ideal for wild watermelon although it is very sensitive to the combination of high humidity and low temperatures (20°C) because of leaf disease development. It is a drought tolerant crop as it thrives well under dry-land conditions of 250mm to 500mm seasonal rainfall due to its root morphogenesis (Yoshimura *et al.*, 2008). Although drought-tolerant, a steady supply of water for best fruit production is needed for watermelon (Schippers, 2002; Botha, 2005; Anomymous, 2008).

Watermelon in general grows well at temperatures from 21°C to 32°C and 18°C to 21°C during the day and night, respectively (Dept. of Agriculture, 2008, currently known as Department of Agriculture, forestry & fisheries, DAFF) and it is a day neutral plant. The ideal time to plant wild watermelon in the western segment of the Eastern Cape would be in summer when the mean temperature for the months of November, December and January is 22°C and the days are long and hot.

1.4.2 Soil requirements

Wild watermelon is often grown successfully on soils of low fertility (Anonymous, 2008), which explains its existence within the small-holder farming community. The crop has been reported to grow well in soils with a pH ranging between 5.0 and 8.0 (Anonymous, 2008), but it grows best at pH 6.0 to 7.0 (Botha, 2005; Smith, 2006).

Literature indicates that wild watermelon can grow in any type of soil, but does best when it is grown on well drained sandy-loam with good moisture retention capacity and high organic matter (Botha 2005; Anonymous, 2008). Botha (2005), citing van der Vossen et al. (2004), stated that best seed germination temperatures for the crop are 17°C-22°C at night and 32°C during the daytime, hence 25°C and 18 to 20°C are regarded as maximum and optimum soil temperatures, respectively.

1.4.3 Propagation and planting

Propagation of cucurbits is usually by means of seed, which may be direct seeded in the field and occasionally grown in seed-trays as seedlings depending on growth factors (Smith, 2006; Maynard, 2007; Anonymous, 2008).) Upon direct seeding, one to three seeds are sown from which the seedlings are later thinned to one per station while transplants can be planted upon first true leaf emergence (Smith, 2006; Anomymous, 2008). Recommendations on seeding rates for gem squash and butternuts are 2 to3 kg ha^{-1} and 4 to 6 kg ha^{-1}for Hubbards and pumpkin (Smith, 2006). No literature could be accessed on the recommended seeding rate for wild watermelon. Coertze, (1996) found the optimum planting density for conventional watermelon to be 6000 to 9000 plants ha^{-1}.

Although wild watermelon is known to be a low input crop that can grow on a variety of soils, literature shows that fertilizer application can improve yields. According to Schippers (2000), a compound fertilizer 15:15:15 (N.P.K.) at the rate of 200 kg ha^{-1} can be applied before sowing. Based on the fertility status of a variety of soils where it can grow, Smith (2006) suggested a fertilization guide for trailing cucurbits (wild watermelon) to be 400 and 800 kg ha^{-1} 2:3:4 (30) at planting and topdressing with LAN (28% N) at 250 and 150 kg ha^{-1} six weeks after emergence for high and low fertility soils, respectively. Based on the fertilization guide, the yield ranges from 12 to 15 tons per hectare while on average it is 17 to 20 tons. Moreover, (Dauda *et al.*, 2008) reported that the crop also responds well to manure.

1.4.4 Crop diseases and pests

According to Schippers (2000), watermelons are susceptible to a range of diseases, which is why they grow best under dry conditions. Major diseases include bacterial fruit blotch, damping off, anthracnose, powdery and downy mildew, *Fusarium* wilt, gummy stem blight and various viruses (e.g. watermelon mosaic virus) (Coertze, 1996; Botha 2005; Anonymous, 2008). Excessive rainfall and high humidity promote excessive vegetative growth and encourage development of leaf diseases (Botha 2005; Anonymous, 2008).

In watermelon, downy mildew is the most economically important disease caused by *Pseudoperonospora cubensis* under humid conditions. Damping off, which is caused by *Marcophomina phaseolina* can be problematic at the seedling stage if planting is done during a rainy season (Schippers, 2000).

Field studies have shown that a number of watermelon varieties are resistant to *Fusarium* wilt, and these should be used where soils are infected with the fungus. Viral disease transmission can be prevented by controlling aphids and cucumber beetles as they are the agents of viral transmission ((Anonymous, 2008).

Melon fly (*Bactrocera Cucurbitae*) is considered as the most serious pest in Africa however wild strains are known to remain unaffected by the pest (Schippers, 2000; Anonymous, 2008). Diseases and pests can be controlled chemically using pesticides and non-chemically. Use of a disease free-fruit for selection of seed for planting, planting earlier in the season and application of a four year period of rotational system to lessen the disease problem is recommended (Coertze, 1996; (Anonymous, 2008).

1.4.5 Harvesting and storage

Unlike other cucurbits, such as squashes and zucchini, that are harvested when immature, watermelons and other melons are harvested when they are fully ripe at 120 to 130 days after planting (Coertze, 1996; Smith, 2006; Omafra, 08/09). As is the case with other cucurbits, such as pumpkin, watermelon's harvest maturity is identified by yellowing of the ground spot on the bottom of fruit, wilting of tendril near the place of fruit attachment as well as a dull sound of the fruit when tapped (hit with a flat hand on the side of a fruit) (Maynard, 2007; Wehner and Gusmini, 2007; (Anonymous, 2008). Reportedly, yields of cucurbits range from 12 to 15 tons per hectare and on average 17 to 20 tons per hectare (Smith, 2006). Literature on handling and storage show that fruits are sometimes left in the fields or piled up at the homesteads. The piling up serves as a convenient store of food and water for a year without losing quality (Smith, 2006). No literature could be accessed on the yields of wild watermelon as such except for prolificacy of the plant, which had been recorded in Botswana to be at a maximum of about 8 fruits per plant (Anonymous, 2008).

1.5 Problem statement, hypothesis and objectives

Indigenous watermelon has always had a special place in many African cultures and that is evidenced by the fact that they are still produced these days by smallholder farmers. The existence with the users are due to their own qualities such as low management practices and survival mechanisms in harsh environments (Backeberg and Sanewe, 2010; Zulu and Modi, 2010). Indigenous crops are characterized as less researched crops because there is insufficient agronomic knowledge to advise farmers (Policy on sustainable development, 8th draft). The

National Agricultural Research and Development Strategy (Department of Agriculture, 2008) recognizes the urgency of more agronomic research of indigenous crops as alternative crops for food security. There are no records as yet on the production of wild watermelon with reference to optimum planting density and effects of mulch on growth and its development. More research on agronomic aspects of wild watermelon production will provide information and knowledge that could help in promoting the utilization of the crop to ensure food security. Therefore the aim of the study was to generate and document information on agronomic aspects with respect to population density and mulch effects on wild watermelon production. The null-hypothesis for he study was that population density and mulching have no effect on growth and yield of wild watermelon. The objectives of the study were:

a) To determine the effects of population density on growth and yield of wild watermelon under field conditions and

b) To investigate the effects of mulching on growth and yield of wild watermelon under field conditions.

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CHAPTER 2

EFFECTS OF SOWING DENSITY AND MULCHING ON CROP ESTABLISHMENT AND YIELD

2.1. Introduction

Propagation of plants is the multiplication or establishment through seed (sexually) or vegetative parts of a plant (asexually). Seed is the most used form of propagation with agronomic crops such as wild watermelon. A viable seed, as a reproductive unit, must be able to germinate and establish seedlings (McDonald & Copeland, 1997). Germination is the growth of an embryonic plant contained within a seed resulting in the formation of a seedling [Association of Official Seed Analysts (AOSA), 1996]. Seed germination of plant species sown in either field or in a transplant production system is influenced by internal and external factors, and is important in determining the economic success of the crop. Temperature, water, light and oxygen are the most important external factors that have a profound influence on seedling emergence (Hergarty, 1973; Khan et al. 1979; Thomas, 1981 cited by Zulu, 2010). Seeds often have a temperature range above or below which they will or will not germinate and this is closely linked to ecological conditions of a plant’s natural habitat. Seeds of different species and even seeds of the same plant germinate over a wide range of temperatures. Cucurbit seeds require high temperatures for successful germination and seedling emergence (Salmasi, 2006). Botha (2005) citing van der Vossen et al. (2004) stated that the best air temperature for germination of *Citrullus lanatus* seed is 17^0C-22^0C at night and 32^0C during the daytime and 25^oC and 18-20^oC are regarded as maximum and optimum soil temperatures, respectively. Asynchronous seedling emergence, as a result of low temperatures after sowing warm-season crops, causes yield reductions because of increased variation in plant development (Hegarty, 1973 cited by Zulu, 2010).

Yield is determined by the amount of incident solar radiation, temperature and plant density; the latter determining the rate at which the leaf canopy develops under a given solar radiation and temperature regime. Plant density can affect the yield potential at a given site by influencing the utilization of available solar radiation and soil moisture reserves during the growing season (Sangoi, 2000).

Determination of the lowest plant population density necessary for optimal yield is a major agronomic goal (Carpenter and Board, 1997), because it affects plant architecture, thereby influencing carbohydrate production and partitioning (Sangoi, 2000).

Although Eastern Cape farming communities use modern farming systems, the majority of small-holder farmers still practice multiple cropping (Mhlontlo, 2008 citing Silwana, 2000 and Ncube, 2003). One of the major reasons for multiple cropping is lack of good agricultural land for crop production (Mukhala et al. 1999 cited by Mhlontlo, 2008). Intercropping, as one of the multiple cropping systems practised in the Eastern Cape, is defined as the simultaneous growing of two or more crops on the same piece of land (Ncube, 2003); for example, pumpkins and melons are often intercropped with maize (Silwana, 2000; Schippers, 2000; Jansen van Rensburg et al. 2007). Silwana, (2005) reported that higher yields are usually obtained from intercropping because the component crops complement each other, thereby making better overall use of resources. Intercropping also acts as a live mulch thereby suppressing weeds without requiring application of organic or inorganic materials. It could be an option to look at different approaches to mulching in terms of costs of getting mulch material and the labour required to apply it.

Mulching, as a crop production technique, involves placement of organic or inorganic materials on the soil surface, so as to provide a more favorable environment for plant growth and development (Korir et al. 2006). Literature reveals that mulch suppresses weeds, conserves moisture and regulates soil temperature for plant growth and development (Yakubu and Karaye, 2006; Korir et al. 2006; Cook, et al. 2006 and Debashis et al. 2008). Weed management has been identified as the most important limiting factor in crop production including cucurbits in South Africa and elsewhere (Fanadzo et al. 2010) as they result in extensive financial losses. Wild watermelon is grown by small-holder farmers in the Eastern Cape, so they do not have money to buy herbicides as they are expensive. This calls for alternative weed management strategies that will be suitable and readily available for them. The strategies could be an establishment of a good crop stand in which plants emerge and rapidly shade the ground thereby smothering late emerging weeds (Fanadzo et al. 2010 citing Stall, 2006). Establishment of higher populations was also found helpful in reducing weed competition in butternut. Research indicates that increasing crop density can maximize the space occupied by the crop early in the season and put competitive pressure on weeds (Fanadzo et al. 2010 citing Finney and Creamer, 2008). Use of plastic mulches (inorganic materials) and straw (organic materials) has been documented with watermelons and melons quite extensively (Hansen, 2010) but there are no reports as yet on mulching of wild watermelons. There is a need to also examine the response of wild watermelons to mulch for development of appropriate technical advisory packages hence mulch using *Panicum maximum* Jacq. at different rates was used as it is easily or readily available for the wild watermelon farmers. Therefore, the objective of this study was to determine the effects of sowing density and mulching on crop establishment and yield.

2.2. Materials and methods

2.2.1. Description of study site.

The study was conducted at Campagna, Döhne Agricultural Development Institute (DADI) in the Amahlathi District, Eastern Cape Province, which is geographically located at 32°31´S, 27°28´E, at an altitude of 780 m. The study was implemented in 2009/2010 growing season and with an annual rainfall of 750 mm. The mean annual rainfall for Dőhne, Stutterheim (32^{o}31$'$S, 27^{o}28$'$E), where this study was undertaken ranges between 600mm and 1000mm. Most of this rainfall is received during the summer season between the months of October and April. The mean monthly rainfall and temperature during the growing season are shown in Table1.

Table 1: Monthly rainfall and temperature distribution at the experimental site (Campagna, Döhne) during the growing season of 2009/2010.From: ARC Soil Climate & Water weather services

Month	Rainfall (mm)	Temp (^{o}C)
October	66.6	16.91
November	53.1	18.45
December	28.2	19.56
January	106.3	21.86
February	88.7	23.48
March	80.8	21.76
April	31.1	18.81

Soil samples were randomly taken before planting at the experimental site, bulked, air dried and analyzed for nutrient content. The soil at the experimental site was classified as sandy-clay-loam soil. The soils are classified as Oak leaf form, are very deep, well drained, aerated, and thus of moderate to high agricultural potential. Details of soil mechanical and chemical characteristics are given in Table 2.

Table 2: Soil mechanical and chemical characteristics of the experimental site

Mechanical analysis (%)					**Chemical Analysis mg(kg) soil**					
Sample density (g/ml)	**Medium Sand %**	**Fine Sand %**	**Silt %**	**Clay %**	**N%**	**Ca**	**Mg**	**P**	**pH**	**K**
1.32	12.8	50.1	9.4	27.8	0.03	1396	318	33	5.5	80

2.2.2 Planting material

Wild watermelon seed used for the study was supplied by the University of KwaZulu-Natal. It was called Centane accession (Fig.1) according to its locality where it was collected, Centane (in the Eastern Cape). *Panicum maximum* Jacq. (Fig.2) grass was the organic material used as a mulching material as it is readily available.

Figure 1: Centane accession used in this study. Figure 2: *Panicum maximum* Jacq. dry biomass.

2.2.3 Experimental design

The experiment was a combination of population densities and mulching laid in a randomized complete block design with three replications. The four population densities were (3000, 6000, 9000 and 12000 plants /ha) based on the commercial watermelon's optimum density that was found to range from 6000 to 9000 plants/ha (Coertze, 1996) and three mulching rates based on the availability of grass were 0, 2.5 and 5t/ha of grass, *Panicum maximum* Jacq.

The 12 treatment combinations were:

A = 1.1 (3000 plants/ha) at 0 mulching,

B = 1.2 (6000 plants/ ha) at 0 mulch,

C = 1.3 (9000 plants/ha) at 0 mulch,

D= 1.4 (12000 plants/ha) at 0 mulch,

E = 2.1 (3000 plants/ha) at 2.5t/ha mulch,

F= 2.2 (6000 plants/ ha) at 2.5t/ha mulch,

G= 2.3 (9000 plants/ha) at 2.5t/ha mulch,

H= 2.4 (12000 plants/ha) at 2.5t/ha mulch,

I = 3.1 (3000 plants/ha) at 5t mulch,

J= 3.2 (6000 plants/ha) at 5t/ha mulch,

K= 3.3 (9000 plants/ha) at 5t/ha mulch and

L= 3.4 (12000 plants/ha) at 5t/ha mulch

The field layout is shown in the **Appendix 5.**

2.2.4 Experimental procedure, data collection and statistical analysis

2.2.4.1 Experimental procedure

The land was ripped before ploughing to break the plough pan and thereafter conventionally prepared. A basal fertilizer treatment at the rate of 100 kg 2:3:4 (30), 100kg LAN and 50 kg KCl were applied to all plots based on the soil analysis results for melon production.

The entire experiment consisted of thirty six plots and each plot was 36 m^2 consisting of four rows each where two middle rows in each plot were used for data collection. The sowing date for the experiment was 6 November 2009. Seeds were sown by hand directly in the field at an inter-row spacing of 2.1m and an intra-row spacing of 160, 80, 53 and 42 cm. Three seeds were planted per hole and plants were later hand-thinned to one per stand, two weeks after emergence. Cutworm bait was applied immediately after planting as a control measure against cutworms.

Weed control of the experiment was done two weeks after emergence through manual hoeing with simultaneous hand-pulling around the plant. Application of mulch treatments (0, 2.5t and 5t) of designated plots was done immediately after weeding. Weeding control of the experiment was only done once before the mulch application.

2.2.4.2 Data collection

Soil temperature was measured 10-15 cm below the soil surface by using a digital thermometer in each plot during the day for approximately (10H00- 10H05) every week from planting until harvesting. Soil moisture was sampled at 15 cm depth weekly below the soil surface by manual coring and gravimetric moisture content of the soil samples was calculated on oven-dry weight basis to determine volumetric moisture content using equation: $\theta v = \theta m. \rho s/\rho w$ (FSSA, 2000);where: θv =Volume base, $\theta m = M_{w/}M_s$, M_w= mass water (kg), $M_{s\,=}$ mass oven dried soil (kg), ρs = bulk density of soil (kg m^3), ρw = density of water (kg m^3).

Three plants were randomly selected from two middle rows per plot a week after mulch application for data collection. Data regarding vine length, vine number (branches) and leaves were recorded on a weekly basis until 50% flowering. Data recording on the above growth parameters occurred twice due to severe hailstorm damage that occurred on 6 January 2010. The recovery period for watermelon took two weeks and thereafter the crop reached 50% flowering stage which resulted in termination of data collection. The length of the vines was measured using a meter rule and vine number (branches) and leaves were determined by manual counting.

The weed density was measured in order to know the number and nature of weeds competing with the crop as well as the smothering effect of plant population and mulch. The weed density was measured using a counting method whereby a quadrat of 50 cm x 30 cm was placed at three random locations per plot. Weed species from each plot were identified, counted and classified according to their morphology classes (grasses, broad-leaved or sedges) to determine infestation levels.

At harvest, fruit number, fruit grading (weights) and total yield (fruit mass) per plot was used to determine yield. The effect of population density and mulch on market quality of fruit was also determined where fruits were divided into size classes based on 2.5- 5kg increments as small (< 2.5kg); medium (2.6 – 5kg); large (5.1kg – 10kg) and very large (> 10kg). Available watermelon market prices (Bloemfontein, Cape Town and Durban markets) were only for medium (6kg) and small (3kg) sized fruits with the latter fetching the higher price of R10.00 than medium (Appendix 3 C).

2.2.4.3 Statistical analysis

Data were analyzed by two-way analysis of variance (ANOVA) by treatment and block using Genstat 14th edition to generate values of least significant differences, which were declared significant at 5% level. Least Significant Difference (LSD 5%) was used to separate means. Descriptive statistics (mean, standard deviation and coefficient of variation) were also generated using Genstat 14th edition. Analysis of variance tables for each variable are presented (Appendix 2).

2.3. Results and discussion

2.3.1 Influence of population density and mulch on soil temperature during the growing period

Table 3 showed the significant influence of population density and mulch on soil temperature. With respect to population density, there was no significant effect ($P > 0.05$) on soil temperature. The interaction of population density and mulch also showed no significant effect ($P > 0.05$) on soil temperature. Higher mulch rate (5t/ha) resulted in a significantly low soil temperature ($P < 0.001$) than 2.5t/ha and 0 t/ha mulch. This showed that the effect of mulch on the soil temperature depends on the density of the mulch that is the higher the mulch the lower the soil temperature. The observation is in agreement with the findings of Cook et al., (2006) who reported on reduced temperature with increased straw mulch in maize.

2.3.2 Influence of population density and mulch on soil water content during the growth period

Population density and mulch significantly reduced and increased soil water content (Table 3). Low population density (3000 plants/ha) had the highest water content ($P < 0.004$) compared to all other population densities. The soil water content was significantly affected by mulch ($P < 0.001$). The interaction of population density and mulch had no effect ($P > 0.05$) on soil water content. The high moisture content at 3000 plants/ha was possible that the plants experienced little or no competition for limited environmental resource (water) compared to increased plant population. The water content among mulch rates was significantly different to each other with less water at no mulch compared to mulching. This showed that the higher the mulch density, the higher the soil water retention capacity and that mulch has the ability to modify the radiation budget of soil surface thereby suppressing soil water evaporation (Korir *et al*., 2006; Cook *et al*., 2006).

2.3.3 Effects of population density and mulching on growth of wild watermelon

2.3.3.1 Vine length

Vine length was not affected by mulching, density or their interaction ($P > 0.05$) (Appendix 2 D). Although population density had insignificant effect on vine length, a trend of shorter vines as population density increased was observed. Low population density (3000 plants per ha) had longest vine (1.81m) compared to all other population densities and also 2.5t/ha mulch produced longer vines compared to 5t/ha and 0t/ha mulch. With respect to the interaction of population density and mulch, low population density in combination with 2.5t mulch had longest vines (1.97m) compared to all the treatment combinations. This concurred with reports of Parkinson *et al.* (1999) and Sellers *et al.* (2001) cited by Cook *et al.* (2006) that application of mulch presents opportunities for improved soil and water relations for crop development.

2.3.3.2 Number of branches or vines per plant

Population density, mulch and their interaction did not affect the number of branches or vines per plant (P > 0.05) (Appendix 2C). Similar trend as in vine length was also observed with the number of branches where low population density (3000 plants/ha) had the highest branches compared to all other population densities (Table 3). Mulch rate of 2.5 t/ha had the higher number of branches compared to 0 t/ha and 5t/ha mulch. With respect to the interaction of population density and mulch, the highest number of branches per plant was observed at low population density in combination with 2.5t/ha mulch compared to all other treatment combinations. Although the number of branches per plant was not affected (P > 0.05), a trend of increased branch development per plant under mulching in combination with low population density (3000 plants) was observed. This concurred with reports of Parkinson *et al.* (1999) and Sellers et al. (2001) cited by Cook *et al.* (2006) that application of mulch presents opportunities for improved soil and water relations for crop development.

2.3.3.3 Number of leaves per plant

The number of leaves per plant was not affected by population density, mulch and their interaction (P > 0.05) (Appendix 2 E). The number of leaves followed similar trend as in vine length and number of branches per plant. The low population density (3000 plants per ha) had more leaves per plant than all other population densities. The higher number of leaves per plant observed at low population density might be due to luxurious growth of plants as they experienced little or no competition for growth resources compared to other population densities (Ibrahim, 1994; Bodnar et *al.*, 1998). More leaves were observed at 2.5t/ha mulch rate than at 5t/ha and 0 t/ha mulch rate. The interaction of population density and mulch produced highest number of leaves per plant at low population density in combination with 2.5t/ha mulch rate compared to all possible treatment combinations.

Table 3: Soil temperature, volumetric water content and growth parameters of wild watermelon as affected by population density and mulch

Treatments	**Volumetric water content (mm)**	**Soil Temperature °C**	**Height (m)**	**Number of branches**	**Number of leaves**
Plant population(plants/ha)					
3000	3.728 b	24.35 a	1.806 b	4.539 a	89.67 b
6000	3.533 a	24.32 a	1.447 a	4.178 a	76.03 ab
9000	3.517 a	24.46 a	1.643 ab	4.283 a	68.82 a
12000	3.559 a	24.32 a	1.671 ab	4.317 a	76.07 ab
Mulching (t/ha)					
0t	3.092 a	24.64 b	1.552 a	4.329 a	68.78 a
2.5t	3.602 b	24.38 b	1.781 a	4.500 a	80.80 a
5t	4.057 c	23.99 a	1.614 a	4.158 a	80.37 a
P	*	NS	NS	NS	NS
M	**	**	NS	NS	NS
PXM	NS	NS	NS	NS	NS

***Significant differences at P< 0.001; * Significant differences at P < 0.05; NS: No significant difference*

2.3.4 Effects of population density and mulching on yield

The effect of population density and mulch showed significant influence on number of fruits per hectare and total yield and insignificant influence on fruit number per plant, fruit fresh and dry mass. The results showed that watermelon yield per plant tend to decrease with higher population densities while the yield per unit area is increased. The decreased production per plant is due to suppressed growth because of intense interplant competition as population density increases.

2.3.4.1 Fruit number per plant

Population density, mulch and their interaction had no effect on the fruit number per plant (P > 0.05) (Appendix 2 F). With respect to mulch, high mulch rate (5t/ha) produced higher fruit number (1.343) per plant than 2.5 ton and 0t/ha mulched. Population density of 6000 plants per ha produced higher fruit number per plant (1.354) than other population densities. This showed that increasing population beyond 6000 plants per ha negatively affected the fruit number per plant. The decreased number of fruit per plant may be attributed to the reduced fruit set per plant as population density increased. The results are in conformity with Ngouajio, et al., (2006), Motsenbocker, (1996), who reported that fruit per plant in pickling cucumber, pepperoncini pepper respectively was inversely related to population density. Based on the results, 5t/ha mulch rate in combination with 6000 plants/ha produced higher number of fruits (1.402) per plant than all other treatment combinations.

2.3.4.2 Fruit number per hectare

The fruit number per hectare was significantly influenced by population density ($P < 0.001$) (Appendix 2G). Mulching had no significant effect ($P > 0.05$) on the fruit number per plant though higher fruit number (111) at higher mulch rate (5t/ha) was observed. With respect to population density, significantly higher (128) number of fruits per ha was observed at higher compared to lower population (71). This shows that the higher the population density the higher the fruit number per h hectare. In general, high population density (12000 plants/ha) produced most fruits per hectare suggesting that the yield per hectare increase with a narrower spacing is attributable to a higher plant population per unit area than fruit production per plant. Similar results were obtained with melons, garlic and pepperoncini pepper by Ban, *et al.*, (2006); Karaye *et al.*,(2006) and Motsenbocker, (1996) respectively.

2.3.4.3 Fresh fruit mass

Plant population, mulch and their interaction had no effect ($P > 0.05$) on fruit fresh mass though 12000 plants per hectare had greater fresh mass (1.680kg) than all other population densities (Appendix 2 I). Mulch had greater fresh mass compared to no mulch. As mulch increased, fresh mass per fruit also increased. The highest fresh mass (1.846 kg) with respect to interaction of plant population and mulch was observed at 6000 plant/ha in combination with 5t/ha mulch. The increased fruit mass at high population density could be due to total mass per unit area rather than per plant basis based on inverse relationship between population density and fruit number per plant (Ngouajio et al., 2006; Motsenbocker, 1996).

2.3.4.4 Dry fruit mass

The dry fruit mass was not affected by population density, mulch or their interaction ($P > 0.005$) though 6000 plants/ha had higher fruit dry mass (0.3934 kg) than other population densities and also higher mulch rate (5t/ha) produced higher fruit dry mass (0.4054kg) (Appendix 2J). The highest fruit dry mass (0.445 kg) compared to all other treatment combinations was observed at 6000 plants/ha under 2.5t mulch with respect to interaction of population density and mulch. As plant population increased beyond 6000 plants/ha, the dry fruit mass decreased. The decrease in dry fruit mass may be due to intense interplant competition due to more plants per unit area which tends to suppress plant growth (Walters, 2009 citing Duthie et al., 1999a). This is in agreement with Azam-Ali and Squire (2002), who also reported a decline of linear relation between dry matter and increasing population due to shading amongst individual plants.

2.3.4.5 Total yield

Similar trend as that of fruit number per hectare was observed with total yields. With respect to mulch there was no significant effect ($P > 0.05$) although higher mulch rate (5t/ha) had higher yields than 0t and 2.5t/ha mulch. Plant population density had significant effect ($P < 0.001$) on total yield (Appendix 2 H). Significantly higher (215) total yields per ha were observed at higher population density compared to lower (106). The interaction of population density and mulch had no effect ($P > 0.05$) on total yield however high population density (12000 plants/ha) under 5t mulch had higher total yield to all other treatment combinations. In general, high (12000) and low (3000) population density under 5t/ha mulch had significantly higher and lower yields than all other treatment combinations. Based on the results, plant population density had a profound influence on yield per hectare whether mulched or un-mulched hence increased yields at high population density (Ban, *et.al.* 2006, Karaye, *et al.*, 2006 and Motsenbocker, 1996).

Table 4: Yield parameters of wild watermelon as affected bu population density and mulch

Treatments	**Fruit number/plant**	**Fruit number/ha**	**Total Yield (kg/ha)**	**Fresh fruit mass (kg/**plant)	**Dry fruit mass(kg/plant)**
Plant population(plants/ha)					
3000	1.310 a	71.30 a	106.7 a	1.473 a	0.3736 a
6000	1.354 a	104.6 b	170.0 bc	1.612 a	0.3934 a
9000	1.209 a	114.4 bc	159.9 b	1.421 a	0.3301 a
12000	1.207 a	128.6 c	215.4 c	1.680 a	0.3699 a
Mulching (t/ha)					
0t	1.231 a	101.5 a	153.3 a	1.511 a	0.3340 a
2.5t	1.236 a	101.5 a	158.0 a	1.548 a	0.3607 a
5t	1.343 a	111.2 a	177.6 a	1.581 a	0.4054 a
P	NS	**	**	NS	NS
M	NS	NS	NS	NS	NS
PXM	NS			NS	NS

***Significant differences at P< 0.001; * Significant differences at P < 0.05; NS: No significant difference*

2.3.4.6 Effects of population density and mulching on market quality

Population density, mulch and their interaction did not affect fruit size distribution (P > 0.05) however a decreased fruit size (53% increase in the proportion of small fruits compared to medium fruits as population density increased (6000-12000 plants/ha) was observed. Mulching produced less small size fruits than no mulch. In general mulch produced higher percentage of medium fruits (48%) compared to no mulch. Higher production of medium fruits at low population density (3000 plants/ha) under no mulch could be attributed to little or absence of competition for growth factors due to widely spaced than closely spaced plants. The market prices of cucurbits differ in price though their grading is similar (Appendix 3A&B). This shows that good market exists though every season tends to be different and dependent largely on the number of growers and weather conditions affecting the growing season of a particular growing region. Though the sizes might be different, the farmers could be in a better position in terms of profit as higher number of small fruits (medium as per results) was produced at low population density. They would be able to market their fruit as small instead of medium even under not mulching at low population densities. This shows that market research is important as it informs producers of the market requirements. The presence of mulch had resulted in production of higher number of smaller fruits than medium fruits. This implies that the higher number produced at higher population density is the main contributor to the yield (Olufemi, 2006). As watermelon is grown for fruit, so its fruit would be raised by high population density in combination with 5t mulch as it provided more of marketable yield as far as market is concerned.

Table 5: Fruit size distribution of wild watermelon as affected by plant density and mulch

	Fruit size distribution			
2009 -2010 season			**2010 – 2011 season**	
Treatments	**Small**	**Medium**	**Small**	**Medium**
Plant population				
3000	4.403 a	2.807 a	5.379 a	8.104 b
6000	4.464 a	3.061 a	7.094 b	6.303 ab
9000	4.511a	2.482 a	7.362 b	6.075 b
12000	3.629 a	3.587 a	7.094 b	6.573 ab
Mulching (t/ha)				
0t	4.439 a	3.205 a	6.961 a	6.897 a
2.5t	4.173 a	2.882 a	6.762 a	6.772 a
5t	4.143 a	2.866 a	6 527 a	6.623 a
P	NS	NS	*	NS
M	NS	NS	NS	NS
P x M	NS	NS	NS	NS

***Significant differences at P< 0.001; * Significant differences at P < 0.05; NS: No significant difference*

2.3.4.7 Effects of population density and mulching on weed occurrence

Table 6 shows the weed species and their level of infestation at the experimental site during the growing season.) Seventeen weed species were identified during the growing season of wild watermelon and based on their morphology were grasses, broad leaved and sedges. *Digitaria sanguinalis* and *Setaria pallide-fusca (*grass weed species); *Galinsoga paviflora*, *Amaranthus thunbergii* Moq., and *Emex australis (*broad-leaved weed species and *Cyperus esculentes* L. as the only sedge weed species recorded were the most widespread and troublesome weeds as they occurred throughout the treatment combinations. *Digitaria* spp., *Amaranthus* spp., *Cyperus* had been found as most serious weeds in cucurbits (Webster 2002 as cited by Schonbeck, 2011).

Of the three broad-leaved species, *Galinsoga paviflora* was the most problematic weed as its infestation levels ranged from 1% -59%. As it had been cited as troublesome in cucurbit production, its high infestation levels could be due to its extremely short life cycle (30 days from emergence to seed) as it can complete two or three generations in one season (Schonbeck, 2011).

Although *Amaranthus* spp is considered as a weed that can reduce cucumber yields by 10% - 50% depending on their level of infestation in Florida (Berry *et al.*, 2006 as cited by Schonbeck, 2011), here in South Africa it is among more than 100 different popular indigenous leafy vegetables that are most widely consumed (Mhlontlo, 2008 citing Jansen van Rensburg et al., 2004; Laker, 2007). Among the mulching treatments, 5t/ha mulch produced least weeds substantiating the finding of John (2000) who reported that smothering of weeds depends on the thickness of mulch. The results showed that mulch on its own cannot be a viable option for troublesome weed therefore integrated weed management should be considered.

Table 6: Weed species present at the experimental site and their level of infestation per treatment

Weed Species	1:1	1:2	1:3	1:4	2:1	2:2	2:3	2:4	3:1	3:2	3:3	3:4
Grasses	**Level of infestation**											
Avena fatua L.	-	-	-	-	-	-	-	-	x	-	-	-
Digitaria sanguinalis	x	x	x	x	-	x	x	x	x	x	x	x
Eleusine indica (L) Gaertn.	-	-	x	-	-	-	-	x	-	x	-	-
Lolium multiflorum	-	-	-	-	-	-	-	-	-	-	-	x
Setaria pallide – fusca	x	x	x	x	x	x	x	x	xx	x	x	x
Broad leaved												
Amaranthus thunbergii Moq.	x	x	x	x	x	x	x	x	x	x	x	x
Conyza sumatrensis	-	-	-	-	-	-	x	-	-	-	-	-
Emex australis	x	x	x	x	x	x	-	x	x	x	x	x
Galinsoga parviflora	x	x	x	x	xx	xx	xx	xx	x	xx	x	x
Hibiscus trionum L.	x	x	x	-	-	-	x	-	x	-	-	x
Plantago lanceolata L.	x	-	x	x	-	-	x	-	-	x	x	x
Portulaca oleracea L.	x	x	-	-	x	x	x	x	x	-	-	-
Schkuhria pinnata	x	x	x	-	x	x	x	x	-	-	x	x
Solanum nigrum	-	x	-	-	-	-	-	-	-	x	x	-
Sonchus oleraceus L.	-	-	-	-	-	-	x	-	-	-	-	-
Tagetes minuta L.	-	-	-	-	-	-	-	-	-	x	-	-
Sedges												
Cyperus esculentus L.	x	x	x	xx	x	x	x	x	x	x	x	x

Key

1:1 = No mulching at 3000 Plant Population Density; 1:2 = No mulching at 6000 Plant Population Density

1:3 =No mulching at 9000 Plant Population Density; 1:4 =No mulching at 12000 Plant Population Density

2:1 =2.5t/ha mulching at 3000 Plant Population Density; 2:2 =2.5t/ha mulching at 6000 Plant Population Density

2:3 =2.5t/ha mulching at 9000 Plant Population Density; 2:4 =2.5t/ha mulching at 12000 Plant Population Density

3:1 =5t/ha mulching at 3000 Plant Population Density; 3:2 =5t/ha mulching at 6000 Plant Population Density

3:3 =5t/ha mulching at 9000 Plant Population Density; 3:4 =5t/ha mulching at 12000 Plant Population Density

x = Low Infestation (1-39% occurrence); xx = Moderate Infestation (40-59% occurrence)

xxx = High Infestation (60-100% occurrence); = nil

2.4. Conclusion

Wild watermelon growth was not influenced by population density, mulch or their interaction. The vegetative development of wild watermelon was negatively affected by population density that is as population density increased, the vine length, number of branches and leaves per plant decreased. The effect of reduced temperature due to the applied mulch had resulted in more water conservation that was manifested in optimum plant growth (optimum vine length, number of branches and more leaves). Depending on the availability of mulch material, mulching (2.5t and 5t/ha) could be recommended in combination with low population density for optimum wild watermelon growth under similar conditions.

The study demonstrated that wild watermelon was responsive to different population densities and mulch rates in that it resulted in different optimum densities depending on its use. As the crop has various uses such as a leafy vegetable, low population density (3000plants/ha) in combination with 2.5t/ha mulch could be recommended for such purpose as it produced more vegetative growth. Since wild watermelon is mainly grown for fruit by the smallholder farmers, 9000 and 12000 plants/ha in combination with 5t/ha mulch and 0t/ha mulch proved to be more profitable and could be recommended under similar conditions. The study would be beneficial to all farmers irrespective of mulching or not mulching.

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CHAPTER 3

EFFECT OF SEEDLING PROPAGULES AND MULCHING ON CROP ESTABLISHMENT AND YIELD

3.1 Introduction

The use of seed is the manner in which most plants establish naturally and has therefore always been the most common means of crop propagation. The process of establishment begins with seed germination which is dependent on environmental conditions and on seed viability i.e. the ability of the seed to germinate and grow into a seedling (Bewley & Black, 1994). Seedling or transplant is an indirect seed propagation method mostly used for vegetable production while direct seeding is mainly used for agronomic crops but literature suggests that other agronomic crops such as cereals and cucurbits can be propagated using both seed and seedlings (Assefa *et al*., 2007; Ehsanullah *et al*., 2000; Kaveh *et al.,* 2011).

Watermelon as one of cucurbits can therefore be established in the field by direct seeding or use of seedlings (Assefa *et al*., 2007; Ehsanullah *et al*., 2000; Kaveh *et al.,* 2011; Smith, 2006). Direct seeding can result in slow, variable and reduced crop stands where extreme high or low temperatures, water stress, heavy rains or the presence of soil-borne pests and diseases prevail at the time of seeding (Leskovar and Cantliffe, 1993; Zulu, 2010 citing Hegarty, 1973). Reports (Leskovar and Cantliffe, 1993; Carpenter and Board, 1997; Kaveh *et al*., 2011) on benefits of transplants are that of uniform plant stand, tolerance or escape of early environmental or biological stress and earlier maturity than direct-seeded plants. Literature suggests improved grain yields of transplanted rice and sorghum (3.23t/ha, 10-18t/ha) than direct seeding (Ehsanullah *et. al.,* 2000; Assefa *et al*., 2007). Propagation of watermelon using seedlings is unknown by the concerned farmers, raising wild watermelon seedlings and transplanting them could be an option of guarding against environmental conditions that could occur at the time of seeding and could also help minimize the risk of losing their harvest.

In small-holder farming system, cucurbits including wild watermelons are usually intercropped with maize (Silwana, 2000) through direct seeding thereby acting as live mulch. Literature indicates poor weed management as one of the limiting factors in crop production as it results in yield reduction. Wild watermelon producers control weeds culturally (hoeing) as chemical weed control is expensive for them. For these reasons, investigation into alternative cultural weed control strategies that are ecologically friendly, devoid of resistance by weeds and compatible with the wild watermelon producers will be beneficial hence mulching using therefore *Panicum maximum* Jacq. at different rates was used as it is readily available.

In any production system i.e. seed or seedling propagation, there is a population that maximizes the utilization of available resources thereby expressing maximum attainable fruit yield per environment (Sangoi, (2000); Silwana, (2000) citing Holiday, (1960) and Spedding, (1983). Therefore, determination of the lowest plant population density necessary for optimal yield is a major agronomic goal, Carpenter and Board (1997), in any crop production system as it influences carbohydrate production and partition (Sangoi, 2000), hence the objective of the study was to investigate the effect of seedling propagules and mulching on crop establishment and yield.

3.2 Materials and methods

3.2.1 Description of study site

The study was conducted at the Döhne Agricultural Development Institute (DADI) in the Amahlathi District, Eastern Cape Province geographically located (32° 31' S, 27° 28' E) at an altitude of 905 metres in 2010/2011 growing season. The mean rainfall during the growing season was 142.3 mm with maximum and minimum temperature of 20.52 °C and 14.86° C respectively (Table 7)

Table 7: Monthly rainfall and temperature distribution at the experimental site (Döhne) 2010 / 2011

Month	Rainfall (mm)	Temp (^{0} C)
December	189.7	16.64
January	235.1	19.13
February	69.5	20.52
March	146.2	19.26
April	71	14.89

Source: ARC Soil Climate & Water weather services

Soil samples were randomly taken before planting at the experimental site, bulked, air dried and analyzed as a basis for fertilizer recommendations. The soil at the experimental site was classified as sandy-loam soil. Details of soil mechanical and chemical characteristics are given in Table 8.

Table 8: Soil mechanical and chemical characteristics of the experimental site

Mechanical analysis						Chemical Analysis (ppm)					
Coarse Sand %	Medium Sand %	Fine Sand %	Silt %	Clay %	Sample Density (g/ml)	N%	Ca	Mg	P	pH	K
0.3	4.9	64.3	19.4	11.2	1.28	0.09	600	146	41	4.2	390

3.2.2 Planting material

Establishment of wild watermelon seedlings was done in early January whereby seeds from Centane accession were hand sown into four 200 – celled polystyrene seedling trays (about 670mm long, 340mm wide and 60mm deep) that were filled with hygrotech growing mixture (Hygrotech Co. East London, Eastern Cape).

Figure 3 Watermelon seedlings **Figure 4: Panicum maximum Jacq. dry biomass**

3.2.3 Experimental design

The experiment was designed as in Chapter 2; the only difference was the planting material used which were seedling propagules instead of seed propagules.

3.2.4 Experimental procedure, data collection and statistical analysis

3.2.4.1 Experimental procedure

The land was conventionally prepared. Plots received a basal fertilizer treatment at the rate of 100 kg 2:3:4(30), 100kg LAN and 50kg KCL banded in the row. Two true leafed transplants were hand transplanted at an inter-row pacing of 2.1m and intra-row spacing of 160, 80, 53 and 42cm into 8m x 8m plots that consisted of four rows at the end of January 2011. Cutworm bait was applied immediately after planting as a control measure against cutworms.

At two weeks after transplanting, all the experimental plots were hand-weeded and simultaneously grass mulching with *Panicum maximum* Jacq., at different application rates (0, 2.5t and 5t) of designated plots was done.

3.2.4.2 Data collection

Soil temperature was measured 10-15cm below the soil surface in each plot using a digital pocket thermometer every week from planting until harvesting. Soil moisture was sampled at

20cm weekly below the soil surface by manual coring and volumetric moisture was calculated from gravimetric moisture content using the equation: **$\theta v = \theta m. \rho s/\rho w$ (**FSSA, 2000) where:

$\theta v = \theta m = M_w/M_s$, M_w= mass water (kg), M_s = mass oven dried soil (kg), ρs = bulk density of soil (kg m^3), ρw = density of water (kg m^3).

Individual plots consisted of four rows with all data obtained from three randomly selected plants of the two middle rows. Data on vine length, the vine number (branches) and leaves were measured on a weekly basis until 50% flowering. The length of the vine was measured using a meter rule while vine number (branches) and leaves were determined by manual counting. At maturity as indicated by yellowing of the ground spot, fruits were harvested manually, counted and weighed for each plot. Fruit yields were summed and expressed on per plant and per hectare basis. Dry mass per plot was also determined at oven temperature of 75^0C for 48 hours. Occurrence, extent and types of weeds were recorded using quadrat of 50cm x 30cm at three random locations per plot. Weed species in each quadrat were identified counted and recorded for classification and to determine the extent of weed infestation.

3.2.4.3 Statistical analysis

All data collected was subjected to analysis of variance using Genstat version 12.1(UKZN, 2009) and the means that were significantly different (F test) were separated by Fisher's unprotected least significant difference at $P \leq 0.05$. Analysis of variance table for each variable are presented (Appendix 4)

3.3 Results and Discussion

3.3.1 Influence of population density and mulch on soil temperature

Mulch had a significant effect ($P<0.001$) while population density as well as interaction had no effect ($P>0.05$) on soil temperature. Higher mulch rate (5t/ha) resulted in a significantly low temperature ($P<0.001$) than 2.5t/ha and (0t/ha) mulch. The reduced soil temperature at high mulch rate showed the importance of mulch in regulating temperature while increased soil temperatures under not mulch might be due to absorption of most solar radiation by soil surface due to absence of mulch as well as insufficient ground cover. The observation is in conformity with Gardener (1985) who reported little absorption of radiant energy at early plant growth stages due to small leaf area. The reduction of soil temperature as observed with increased mulch rates (5t) is in conformity with the findings of Cook *et al.*, (2006) who reported reduced temperature with increased straw mulch rates in maize.

3.3.2 Influence of population density and mulch on volumetric water content

Table.9 shows that population density, mulching and their interaction had a significant influence on volumetric water content. The low population density (3000 plants/ha) had the highest water content ($P<0.001$) compared to all other population densities. Higher mulch rate (5t/ha) resulted in a significantly increased moisture content ($P<0.001$) than 2.5t/ha and (0t/ha) mulch. The interaction of population density and mulch also showed an effect on volumetric water content ($P<0.044$). Conservation of less water at high population density might be attributed to interplant competition of water resource due to increased population density per unit area (Maynard and Scott, 1998 as cited by Ban, *et.al.* 2006).The higher soil moisture content under mulching indicated the role of mulch in soil moisture conservation. The high soil water conservation at highest mulch concurs with findings of Debashis, *et al.*, (2008); Cook, *et al.*, (2006) and Ramakrishna *et al.*, (2006) who also found that mulches whether organic or inorganic increase the soil water status upon application thereby improving the soil conditions for crop development.

3.3.3 Influence of population density and mulch on wild watermelon's growth

3.3.3.1 The vine length

The results show that plant population, mulching or interaction had no effect on vine length or height of the plant ($P>0.05$). Varied plant height was observed although tallest plants (1.704m) were recorded at 6000 plants per hectare than all other population densities. Plants that had longest vines (1.697m) were also observed under 2.5t/ha mulch compared to 0t/ha and 5t/ha. The interaction of population density and mulch had longest vines at 6000 plants/ha in combination with 2.5t/ha mulch. Based on the results obtained, it showed that mulching beyond 2.5t had a negative effect on plant height hence shortest plants at 5t/ha mulch. This showed that plant height is depended on amount of solar radiation intercepted when water is not limiting as temperature and photoperiod are regarded as determinants of potential duration of each developmental phase of the crop (Azam-Ali and Squire 2002).

3.3.3.2 The vine number per plant

The population density, mulch and their interaction did not have an effect ($P>0.05$) on number of vines per plant. Highest number of vines per plant (4.956) was produced at no mulching than at mulching. Production of the highest number of vines per plant with respect to population densities was observed at 3000 plants/ha. A trend of decreased vine development as population and mulch increased was observed. The result could be as a result of competition among plants under high density conditions. The findings are in accordance with Khalid (2010) who found similar results with cucumber. The presence of mulch decreased soil temperature and consequently branch development as each growth phase has its own optimum for its development (Azam-Ali and Squire, 2002).

3.3.3.3 The number of leaves per plant

Neither population density nor mulching effect showed any significant difference on the number of leaves per plant ($P > 0.05$). A population density of 6000 plants/ha had more leaves compared to other densities. More leaves were also observed at 0t/ha mulch than 2.5t and 5t/ha mulch rates. A trend of decreased leaf development as population and mulch increased was observed as was the case with vine number was also observed. The findings are in accordance with Khalid (2010) who found similar results with cucumber. The interaction of population density and mulch had an effect (P 0.027) on the leaf number per plant (Appendix 4E). No mulch at 6000 plants per hectare in combination with 2.5t/ha had more leaves (85) compared to all other treatment combinations. According to Azam-Ali and Squire (2002), the potential duration of each developmental phase of a crop such as leaf production is influenced by prevailing temperature and photoperiod.

Table 9: Soil temperature, volumetric water content and growth parameters of wild watermelon as affected by population density and mulch

Treatments	**Volumetric water content (mmH20)**	**Soil Temperature °C**	**Height (m)**	**Number of branches**	**Number of leaves**
Plant population(plants/ha)					
3000	5.953 d	20.55 a	1.658 a	5.041 a	67.12 ab
6000	5.563 c	20.44 a	1.704 a	4.733 a	69.49 b
9000	5.206 b	20.45 a	1.487 a	4.567 a	58.30 a
12000	4.794 a	20.53 a	1.684 a	4.411 a	60.84 b
Mulching (t/ha)					
0t	5.078 a	20.71 c	1.630 a	4.956 a	66.26 a
2.5t	5.436 b	20.51 b	1.697 a	4.558 a	62.69 a
5t	5.608 c	20.26 a	1.573 a	4.550 a	62.87 a
P	**	NS	NS	NS	NS
M	**	**	NS	NS	NS
PXM	*	NS	NS	NS	*

***Significant differences at P< 0.001; * Significant differences at P < 0.05; NS: No significant difference*

Population density and mulch significantly affected the growth of wild watermelon though it was insignificant with plant height. The population density of 12000 and 6000 plants/ha under mulching (2.5t/ha) produced tallest plants (1.87m and 1.80m) than 6000 plants/ha at no mulching (1.77m). With respect to number of branches and leaves, 6000 plants/ha at no mulching had more branches and leaves than12000 and 6000 plants/ha under mulching. This indicated that mulching had a negative effect on branch and leaf development as the height increased the number of branches and leaves decreased. Based from the results in general, 6000 plant density under no mulch produced tallest plants (1.77m) with more branches (5.67) and higher number of leaves (85.33). The higher plant biomass might be attributed to the fact that plants widely spaced, experienced little or no competition for limited environmental resources compared to closely spaced plants. The results are in conformity with Ibrahim (1994) and Bodnar et al. (1998) cited by Yakubu and Karaye, (2006) that widely spaced garlic plants tend to grow more vegetatively and bear more branches and leaves per plant.

3.3.4 Effects of population density and mulching on yield

3.3.4.1 Fresh fruit mass

The population density, mulch and their interaction did not have an effect ($P > 0.05$) (Appendix 4 H). Low population density (3000plants/ha) had highest fresh mass (1.750kg) than all population densities. The highest fresh mass (1.664kg) with respect to mulch was observed under high mulch compared to 2.5t/ha and 0t/ha mulch rate. A trend of increased fresh weight at low population density and high mulch rate was observed. The higher fruit weight may be attributed to the growth conditions namely low population density and more water that plants experienced during growing season. This indicated the positive effects of mulch on moisture retention, efficiency of water uptake and fertilizer use by plants which became manifested in weight of the fruit. The results are in conformity with that of Motsenbocker, (1996); Yakubu and Karaye, (2006) and Aguyoh *et al.,* (2006) who reported that plants at wider spacing tend to grow luxuriously because of unlimited growth factors.

3.3.4.2 Dry fruit mass

Plant population density had no effect on fruit dry weight($P > 0.05$) though 9000 plants per hectare had higher dry weight (0.3706kg) than all other population densities (Appendix 4 I). No mulch (0t/ha) had higher dry weight (0.3669kg) than mulching although the difference was not significant ($P > 0.05$). Mulch indicated a negative effect on dry weight per fruit. The interaction of population density and mulch had no effect ($P > 0.05$) on fruit dry weight though population density of 9000 plants/ha under 5t/ha mulch had highest dry weight (0.398kg) to all other treatment combinations. Higher plant population and mulch had lowest dry fruit weight. The decrease in fruit weight may be due to interplant competition due to more plants per unit area. This is in agreement with Azam-Ali and Squire (2002), who reported a decline in linear relation between dry matter and increasing population due to shading by individual plants.

3.3.4.3 Fruit number per plant

There were no differences ($P > 0.05$) on fruit number per plant irrespective of population density or rate of mulching (Appendix 4F). However, a trend of reduced fruit number per plant as population density increased had been observed especially beyond 6000 plants per hectare and not mulch (0t/ha) tended to have higher fruit number (1.241) than mulching. The decreased number of fruit per plant as population density increased may be attributed to the reduced fruit set per plant due to interplant competition. The results are in conformity with Ngouajio et al. (2006), Motsenbocker (1996), who reported that fruit per plant in pickling cucumber, pepperoncini pepper respectively was inversely related to population density.

3.3.4.4 Fruit number per hectare

Mulching had no effect (P > 0.05) on fruit number per hectare though 0t/ha mulch had higher fruit number (102) than mulching. The fruit number per hectare was affected by population density (P < 0.001) (Appendix 4 G). Significantly higher (123) total yields per ha were observed at higher population density compared to lower (71). The interaction of population density and mulch had no effect (P > 0.05) on total yield however, high population density (12000 plants/ha) under 2.5t mulch had higher total yield to all other treatment combinations. The results suggested that the yield per hectare increase was attributable to a higher plant population despite fruit production per plant. Similar results were obtained with melons by (Ban, et.al. 2006), garlic, (Yakubu, and Karaye, 2006) and pepperoncini pepper (Motsenbocker, 1996).

3.3.4.5 Total yield

Total yield per hectare increased significantly (P < 0.001) up to the 12000 ha population density (Appendix 4 J). There were no significant differences between mulching treatments nor were there any interactions between mulching and plant population (P > 0.05). Higher and lower population density had significantly highest (203.8) and lowest (124.5kg/ha) total yields (Table 10). Higher population density (12000) at 5t/ha and lower population density (3000) at not mulch had significantly highest (213kg/ha) and lowest (114.3 kg/ha) total yields compared to all treatment combinations. In general, high population density (12000 plants per hectare) under 5t/ha mulch produced highest total yields compared to all other treatment combinations. Based on the results, it was clear that yield was more influenced by plant population density than fruit number per plant hence increased yield as density increased (Ban, *et al.*, 2006, Yakubu and Karaye, 2006 and Motsenbocker, 1996).

Table 10: Yield parameters of wild watermelon as affected by population density and mulch

Treatments	Fruit number/plant	Fruit number/ha	Total Yield (kg/ha)	Fresh fruit mass (kg/plant)	Dry fruit mass(kg/plant)
Plant population(plants/ha)					
3000	1.301 a	71.00 c	124.5 c	1.750 a	0.3572 a
6000	1.227 a	94.70 b	147.3 bc	1.563 a	0.3397 a
9000	1.179 a	111.8 a	174.3 b	1.567 a	0.3706 a
12000	1.161 a	123.6 a	203.8 a	1.650 a	0.3507 a
Mulching (t/ha)					
0t	1.241 a	102.2 a	166.2 a	1.638 a	0.3669 a
2.5t	1.206 a	98.90 a	156.0 a	1.595 a	0.3602 a
5t	1.205 a	99.70 a	165.3 a	1.664 a	0.3365 a
P	**NS**	**	**	**NS**	**NS**
M	**NS**	**NS**	**NS**	**NS**	**NS**
P x M	**NS**	**NS**	**NS**	**NS**	**NS**

***Significant differences at P< 0.001; * Significant differences at P < 0.05; NS: No significant difference*

3.3.4.6 Effects of population density and mulching on market quality

Population density had significant effect (P 0.024) on fruit size distribution (Appendix 4K). There were no significant differences between mulch treatments nor were there any interactions between mulching and plant population ($P > 0.05$). The effect of population density influenced the market quality of fruit resulting in fruit size variation (small and medium). Low population density (3000 plants/ha) whether mulched or not mulched had low percentage of small sized fruits compared to all other treatment combinations. The decrease in fruit size (higher percentage of small fruits) as population density increased was observed meaning that the higher the population, the smaller the fruit. This shows that the fruit size is inversely proportional to population density. The decrease in fruit size could be due to decreased photosynthetic capacity of the plant due to poor leaf development caused by competition among the plants as the population increased. The results are in conformity with Watanabe et al. (2003) who reported decrease in fruit size among the planting densities as a function of photosynthetic productivity of the whole plant, which is a factor of the total solar radiation. The size of fruit plays an important role in market price determination (Appendix 3 A&B) and the farmers could be in a better position in terms of profit as small fruits (medium as per results) were produced across all treatment combinations. Based on available watermelon market prices small (3kg) sized fruits fetched the higher price of R10.00 than medium sized fruits. Currently, large sized fruits (10kg) cost R30.00 (Appendix 3D) the results could not produce statistically large fruit (data not presented). This shows that the cucurbit market can fluctuate, can be competitive and sometimes profitable though it is narrow. The results also showed that the farmers would be able to manipulate population density to achieve a particular fruit size that would give best profits irrespective of mulch or no mulch.

3.3.3.7 Effects of population density and mulching on weed occurrence

Weeds are plants that grow in unwanted periods of cropping season (Akobundu, 1987; Kostov and Pacanoski, 2007). The economic importance (yield losses) of weeds in crop production differ globally and their variation from crop to crop have been reported in muskmelon and watermelon as 100% by Chiduza *et al.*, 2010; 10% in watermelon by Berry et al. (2006). There were no significant differences between mulch treatments nor were there any interactions between mulching and plant population ($P > 0.05$). The significant difference (P 0.04) was observed with plant population where low population density (3000) had significantly more weeds compared to other densities due to inadequate leaf area as population is sparsely grown. Table.11 shows weed composition and infestation levels on the growth and development of the crop. Twenty one (21) weed species were identified during the growing season of wild watermelon which was grasses, broad leaved and sedges. *Urochloa mosambicens (*grass weed species) and *Galinsoga paviflora* (broad-leaved weed species) were the most widespread and troublesome weeds as they occurred throughout the treatment combinations. *Galinsoga paviflora* was the most problematic weed as its infestation levels ranged from 39%-100%. According to Schonbeck, (2011), *Galinsoga paviflora* is among the troublesome weeds in cucurbit production due to its extreme short life cycle (30 days from emergence to seed). Amaranthus spp. as one of edible leafy vegetable (Mhlontlo, 2008 citing Jansen van Rensburg et al., 2004; Laker, 2007) had a potential to co-exist with watermelon although in other countries like Florida it can reduce yields by 10% - 50% (Berry et al. 2006) as cited by Schonbeck, 2011. This shows that weeds within the context of food production are plants that interfere with cultivation activity positively as they are suitable for human consumption.

Table 11: Weed species present at the experimental plots and level of infestation

Weed Species	1:1	1:2	1:3	1:4	2:1	2:2	2:3	2:4	3:1	3:2	3:3	3:4
Grasses	Level of infestation											
Cynodon dactylon	-	-	-	-	-	-	-	x	-	-	-	-
Digitaria sanguinalis	-	-	x	-	-	x	-	x	-	x	-	-
Eleuisine indica	-	-	x	-	-	-	-	-	-	-	-	-
Panicum schinzii Hack	-	-	x	-	-	-	-	-	-	-	-	-
Setaria pallide - fusca	-	x	-	-	x	x	x	x	-	-	-	x
Urochloa mosambicensis	x	xx	x	x	x	x	x	x	x	x	xx	x
Broad leaved weeds												
Amaranthus deflexus	-	x	x	-	-	-	x	-	-	-	-	-
Bidens pilosa	-	-	-	-	-	-	-	-	x	-	-	-
Cheponodium album	-	x	x	-	-	-	-	-	-	-	-	-
Emex australis	-	-	-	-	x	-	x	-	-	x	-	-
Fumaria muralis	-	-	-	-	-	-	x	-	-	-	-	-
Galinsoga parviflora	xx	x	xxx	xxx	xxx	xxx	xxx	xx	xx	xx	xx	xxx
Lactuca serriola L.	-	-	-	-	-	-	-	-	x	-	-	-
Plantago lanceolata L.	x	-	x	-	x	x	-	-	x	x	-	-
Portulaca oleracea L.	-	x	x	-	x	-	x	-	x	-	-	-
Raphanus raphanistrum	-	-	-	-	-	-	-	x	-	-	-	x
Scleranthus annus	x	x	-	x	x	-	x	-	x	-	-	-
Solanum nigrum	-	-	-	-	-	x	-	-	-	-	-	-
Sonchus oleraceus	-	-	-	-	-	x	-	-	-	-	-	x
Tagetes minuta L	-	x	-	-	-	x	x	-	x	x	-	-
Sedges												
Cyperus rotundus L.	-	-	-	x	x	X	x	-	-	x	-	-

Key: **Note: 1.1** = No mulching at 3000 Plant Population Density; **1.2 =** No mulching at 6000 Plant Population Density**; 1.3** = No mulching at 9000 Plant Population Density; **1.4** =No mulching at 12000 Plant Population Density: **2.1** = 2.5t/ha mulching at 3000 Plant Population Density **2:2**=2.5t/ha mulching at 6000 Plant Population Density; **2:3** =2.5t/ha mulching at 9000 Plant Population Density; **2:4** =2.5t/ha mulching at 12000 Plant Population Density: **3.1** = 5t/ha mulching at 3000 Plant Population Density **3:2**= 5t/ha mulching at 6000 Plant Population Density; **3.3** = 5t/ha mulching at 9000 Plant Population Density**; 3.4** =5t/ha mulching at 12000 Plant Population Density

xxx = High Infestation (60-100% occurrence)

xx = Moderate Infestation (40-59% occurrence)

x = Low Infestation (1-39% occurrence)

3.4 Conclusion

The results of the study indicated that different plant population densities and mulch rates affected plant growth and yield of wild watermelon. Higher plant biomass was produced at 6000 plant density under no mulch resulting in longest vines plants that had adequate branches and higher number of leaves. The higher plant biomass might be attributed to the optimum growth conditions (optimum temperature and water) that prevailed during the growth period. The yields were influenced by population density resulting in increased yields as population density increased irrespective with or without mulch. Fruit size was significantly decreased as the plant density increased. From the result, increasing population density beyond 6000 plants /ha at 0t and 2.5t/ha resulted in higher percentage of small sized fruits than medium sized fruits. The decrease in fruit size could be due to decreased assimilates due to competition among the plants. The results are in conformity with Watanabe et al., (2003) who reported decrease in fruit size among the planting densities as a function of photosynthetic productivity of the whole plant, which is a factor of the total solar radiation.

Therefore it could be concluded that for optimum fruit yield in wild watermelon, irrespective of mulch or no mulch; 80cm intra-row spacing would be adequate. Depending on availability of mulch material, 80 cm intra-row spacing and 2.5 t/ha mulching treatment should be adopted under similar climatic conditions.

3.5 References

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CHAPTER 4

GENERAL DISCUSSION AND CONCLUSION

4.1 Introduction

This study was undertaken over two seasons, during which two different types of propagules were used to grow wild watermelon. The general aim of separating the foci on the two propagule types was to allow adequate data collection time to observe effects on different physical and agronomic aspects. It is important that the findings derived from each season are compared and discussed in order to come up with recommendations for growers of wild watermelons in the future. Hence, this chapter was used to compare of 2010 and 2011 results.

When the study commenced, no available data on the growth, development and response of wild watermelon to varying population densities and mulch was found in South Africa. Literature reviewed relied on trends of cucurbits in general and some other crops. The success of either seed or seedling propagation is influenced by internal (genotype) and external (environment) factors. Ideally conditions for crop establishment and yield either through seed or seedling (transplant) propagation system rarely occur due to limited resources and the farmers are too poor to supply crops with additional inputs. The study focused on adjustment of the biological demands of crop (plant density) and mulching to match the available resources expected during the growing season hence determination of optimum planting density in combination with mulching using *Panicum maximum* Jacq.was investigated. Stand density whether seed or seedling propagules can be manipulated in order to derive the best compensation by good individual plant performance and total plant population therefore the discussion would be presented as a comparison between the seed and seedling propagation and mulching on crop establishment and yield and to conclude as to which would be the best option for the wild watermelon producers.

4.2 Soil temperature

The soil temperature in both years varied in that the 2010 growing season had higher soil temperatures than 2011 and the mean air temperature was 20.1 ^{0}C and 18.1^{0}C (Table 2.1 and 3.1) respectively. This shows that soil and air temperature can change over different growing seasons. Despite the variation between the years, soil temperature was not affected by plant density during the growing season, the difference was observed within mulch treatments such that increased mulch density resulted in decreased soil temperature in both years. The results are consistent with those reported by Cook et al., (2006) who researched with maize under straw mulch.

4.3 Soil water content

The mean monthly rainfall during the wild watermelon growth season was 64.9 mm in 2010 and 142 mm in 2011 (Table 2.1 and 3.1). There was less moisture conserved as population density increased with or without mulching in both years. The less moisture conservation as population density increased could be due to interplant competition for the growth resource (water). Despite a wet and dry year, mulch conserved more water than not mulching. Increased mulch rate resulted in higher soil water retention compared to not mulching in both years in contrast with low soil temperature experienced at high mulch rate. Higher mulch rate (5t/ha) in combination with low population density resulted in increased soil water content. The results of the study could be explained by increased moisture content at mulching which emphasized the importance of mulch in moisture conservation. Similar findings of highest soil moisture conservation at high mulch rate were reported by (Debashis, 2008; Cook, 2006 and Ramakrishna, 2006). This showed that efficient moisture conservation could be maximized through mulching as precipitation is the major water source for agricultural production by small-holder farmers.

4.4. Crop's growth response to seed and seedling propagules

The study conducted shows that the vegetative growth (plant height, number of branches & number of leaves/plant) of wild watermelon propagated using any form of propagation material (seed or seedling) is not affected by the population density and mulch although the longest vines, with the highest number of branches and leaves were observed at 3000 plants per hectare in combination with 2.5t per hectare mulch. The only difference was the height (longest vines) and number of leaves that was observed at 6000 plants per hectare when seedlings were used. The height decreased with increased plant population. This is contrasting with the findings of El-shaikh, (2010) that of positive relationship between plant density and cucumber. However the number of branches and leaves decreased with higher plant populations. Plants at higher densities accumulate less carbon which is not sufficient to support more branching (Rahman et al. 2011). This result could also be explained by the strong competition among plants under high density conditions (Akintoye et al. 2002 cited by El-shaikh, 2010). Plant height and number of branches per plant influence the canopy closure and the insufficient development of the canopy of leaves at lower density limits yield. Based on the study, despite the seasonal weather conditions this may mean that low population density could be the best option for producing more branches per plant when water is limiting (during dry conditions).

4.5 Crop’s yield response to seed, seedling propagules and mulch

4.5 .1 Fruit number per plant

The fruit number per plant was not affected by plant density and mulch irrespective of any propagation material used. The study showed increased number of fruits per plant from 3000 to 6000 plants/ha while an increase beyond that is from 9000 to 12000 plants/ha resulted in a reduced fruit number per plant. The reduced number of fruit per plant could be due to reduced fruit set per plant as caused by interplant competition. The results agree with reports on melons and watermelons by Ban et al., (2006) citing Kultur et al., (2001) and Eldelstein and Nerson (2001) respectively; cucumbers (Ngouajio, 2006); mini triploid watermelon (Walters, 2009 citing Duthie et al., 1999 (a), Motsenbocker and Arancibia (2002) and Sanders et.al., (1999) that closer row plant spacing in watermelon resulted in lower fruit numbers per plant compared to wider spacing.

4.5.2 Number of fruit per hectare

There is a linear relationship between density and number of fruit per hectare regardless of seed or seedling propagules. Low and high plant density had lower and higher fruit number per ha with or without mulch. In contrast to higher fruit set per plant at lower plant density, lower plant density resulted in decreased number of fruit per unit area which may mean that the yield per ha increase could be due to higher plant density than higher fruit production per plant. This showed that regardless of seed or seedling propagules, the fruit number per hectare parameter with or without mulch is influenced by population density rather than number of fruit per plant. This also showed a direct relationship between fruit number per unit area and plant density that is as plant density increased, the total fruit number per ha increased. The results are consistent with the findings in cucumber by (Ngouajioet al., 2006); melons (Ban, et.al. 2006), garlic, (Yakubu, et al., 2006) and pepperoncini pepper (Motsenbocker, 1996).

4.5.3 Total yield

The effect of plant density on wild watermelon total yield was similar to that of fruit number per hectare. The increased total fruit yield as plant density increased in both seed and seedling propagules shows that plant density is the main contributor to higher yields. Low plant density (3000 plants/ha) whether mulched or not mulched had lowest total yield compared to high plant density (12000palnts/ha). The results suggest that increased fruit set per plant as a result of wider spacing (low plant density) did not compensate for the low fruit yield at low density. The increased total yield as per increased plant population also agreed with Yakubu and Karaye, (2006); Ban et al. (2006) citing Kultur et al. (2001) who reported similar findings with melon and watermelon and onion bulbs. As watermelon is grown for fruit, so its yield would be raised by close spacing as against wider spacing.

There was no positive response on both fresh and dry fruit in relation to plant population and mulch as far as seed and seedling propagules are concerned although different fruit mass at different plant densities irrespective of mulching or not mulching were observed (Table.10). The results also show the low plant population and 9000 plants per hectare as optimum densities for greater fresh and dry mass respectively. This shows that total dry matter accumulation is dependent on solar radiation interception which is a function of leaf area hence high dry mass at 9000 plants per hectare while when water is limiting it was observed at 6000 plants per hectare. Seedling propagules produced comparable fruit mass at not mulching than seed propragules while at mulching there was no consistency. The results suggest that optimum population density under not mulching may not be applicable at mulching. This may mean that when water is not limiting the optimum fruit mass could be achieved at lower population density than when it is limiting (Azam –Ali & Squire, 2002). In general seedling propagules(2011) produced higher fruit mass than seed propagules(2010) with the difference being attributed to the variation in weather conditions as 2011 was a rainy year.

4.5.4 Effect of seed and seedling propagules on market quality or fruit size distribution

Seed and seedling propagules responded similarly in terms of fruit size distribution by producing three grade classes namely small (< 2.5kg), medium (2.6 – 5kg) and large (6 – 10kg) (large data not presented). The only difference was the optimum planting density in combination with mulch at which the different grades were produced. The variation in fruit size as influenced by plant population was more pronounced in 2011 compared to 2010 due to seasonal variation. These variations always have an influence on fruit quality and market price. The fruit size decreased as plant population increased. Wider spacing increased fruit size and fruit number per plant resulting in bigger fruits compared to closer spacing regardless of seed or seedling propagules

Both seed and seedling propagules produced a higher percentage of medium fruits at mulching than not mulching. Low population density with seedling propagules resulted in higher percentage of medium fruits irrespective of mulching or not mulching while it was different with the seed propagules except at not mulching. The higher percentage of medium fruits production regardless of seed or seedling at low population density could be attributed to experience of little or no competition of limited growth factors as they were widely spaced. Similar findings by Yakubu and Karaye (2006) also suggested less competition amongst widely spaced plants compared to closely spaced ones. The results concurred with Ngouajio (2006); Walters (2009); Ban, (2006) who also found reduced fruit size as population density increased. This shows that the fruit size can be manipulated through population density depending on the farmer's interests as influenced by the market. This showed that fruit value can vary with size due to a particular market where small or medium or large fruits can be either more or less valuable.

4.5.5 Effect of seed and seedling propagules and mulch on weed distribution

Ideal conditions for crop growth and development rarely occur because of growth limiting factors such as weeds. Weeds are known to be troublesome plants that can reduce yields in muskmelon and watermelon up to 100% Chiduza et al. (2010); 10% in watermelon by Berry et al. (2006) if no control measures are put in place. Generally, small-holder farmers control weeds culturally by hoeing as chemical weed control is expensive for them. Mulching is one of alternative cultural weed control strategies that is compatible with small-holder farmers hence mulching using *Panicum maximum Jacq.*at different rates was investigated.

Growth and development of wild watermelon either through had been affected by weeds despite the morphology and production system (seed or seedling propagules) used. More weed species (21) were identified in 2011 compared to (17) in 2010. The difference in weed occurrence could be due to high moisture content as weeds respond to the environment the same way as crop plants. Identified weed species based on their morphology with both seed and seedling propagules were grasses, broad-leaved and sedges. Within the broad-leaved species, the results showed *Galinsoga paviflora* was the most troublesome weed as it had high infestation levels and occurred in all the treatments regardless of seed or seedling propagules. Schonbeck, (2011), reported similar findings in cucurbit production in Florida that its high infestation levels could be due to its extremely short life cycle of 30 days from emergence to seed. There was variation of weed species with grasses which could be due to variation in weather conditions (with respect to rainfall and temperature.)

Cperus esculentus L. and *Cyperus rotundus L* were the only the treatments with seed propagules. *Cyperus species* like *Galingsoga paviflora* were also reported as most serious weeds in cucurbits (Webster, 2002 as cited by Schonbeck, 2011). Amaranthus species has a potential to reduce cucumber yields by 10% - 50% depending on infestation levels (Schonbeck, 2011 citing Berry et al. 2006), it is also one of the popular indigenous leafy vegetables that are most widely consumed here in South Africa (Mhlontlo, 2008 citing Jansen van Rensburg et al. 2004; Laker, 2007). This means that weeds are also beneficial to mankind as food source. Both seed and seedling propagules had fewer weeds at mulching compared to 0t/ha mulch and as population density increased. Fewer weeds under mulching (2.5t/ha and 5t/ha) compared to 0t/ha mulch showed the importance of mulch in suppressing weeds regardless of seed or seedling propagules fewer weeds were produced as population density and mulch increased. Higher mulch rate produced least weeds which concurred with John (2000) as cited by Yakubu and Karaye (2006) that efficient suppression of weeds depends on the density (thickness) of mulch. The presence of most problematic weeds such as *Galinsoga paviflora* showed that mulching on its own is inefficient for controlling other weeds therefore an integrated weed management for wild watermelon production should be considered.

4.6 Conclusion

The season and the type of propagation medium (seed or seedling) and crop management (plant density and mulch) as according to this study are the important determinants of optimum density in crop production. Plant density manipulates micro environment of the field and affects growth and yield formation of the crop. The most important parameter affected by plant population is the yield compared to vegetative growth. The yield parameter that was most influenced by plant population is the number of fruit and total yield per hectare. The number of fruit and total yields per hectare increased as plant population increased resulting in high yields to range from 9000 - 12 000 plants per hectare such that increased yields with both media used during the study period as the population increased with or without mulching. It is contrary to the optimum plant density (6000 – 9000 plants /ha) which was found by Coertze (1996) for hybrid watermelon. As watermelon is grown for fruit the increased total yields will be realised when planting is done at a narrower spacing than wider spacing. Production of smaller fruits as the population density increased showed that fruit size is influenced by population density, the higher the population density (9000 -12000 plants/ha), the more fruits are produced per unit area, the smaller the fruit size and higher percentage of medium fruits produced at low population density (3000plants/ha) than at increased population densities The farmer would be able to produce marketable size by manipulating the population density. Although some weeds such as *Galinsoga paviflora* occurred at all treatments, whether mulched or not mulched, results obtained showed fewer weeds as population density and mulch increased. This implies that management of weeds rarely relies on a single control practice, therefore integrated weed management should be considered. For better weed control in wild watermelon, 9000 -12000 plants/ha and 2.5t or 5t/ha mulching should be adopted under similar climatic conditions. Based on the results obtained, it is concluded that for optimum fruit yield, 9000 – 12000 plants /ha in combination with 2.5t.ha mulching rate is recommendable.

4.7 Future directions

Although this study revealed the positive effects of (i) using seeds compared with seedlings and (ii) mulching at a medium (2.5/ha) application rate to minimize weeds, there are many gaps that require further research. Questions for future research include:

(i) What is the effect of using wild watermelon as live mulch in growing grain crops under water stress conditions?

(ii) Does a combination of wild watermelon (at different population densities) and mulching have an effect on crop quality with respect to nutritional value?

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APPENDICES

Appendix 1 Climatic data of the study sites (2005 – 2010) Campagna

MONTHLY RAINFALL (mm)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
2005	176	77.6	94.3	58.3	29.3	6.5	2.5	56.3	3	34.3	140.3	16.1	694.5
2006	122.6	122.5	52.6	79.4	55	4.3	2	76.5	37.7	109.4	46.8	76.2	785
2007	86.5	80.3	115.2	37.2	10.3	8.5	1	12	10.9	93	38.6	88.5	582
2008	207.6	63.6	40.1	49.5	1.3	52.4	0	27	10.4	23	96.6	57.7	629.2
2009	69.2	42	9.9	13.5	24	7.6	8.2	0	29.9	66.6	53.1	28.2	352.2
2010	106.3	88.7	80.8	31.1	5.4	23.6	6.6	0	1.3	114.2	80.2	19.1	557.5

Temp. ^{0}C

2005	20.06	20.95	19.21	17.08	15.89	11.83	12.57	12.24	15.70	16.85	17.22	17.33	196.93
2006	20.54	20.91	15.57	16.57	10.69	12.05	13.00	12.40	14.86	16.61	17.59	18.18	188.97
2007	21.19	21.17	18.80	17.93	14.71	11.74	11.69	13.29	16.94	17.19	18.25	20.09	202.99
2008	20.67	22.73	21.02	15.85	16.19	13.04	10.94	13.54	14.59	17.54	19.67	21.68	207.46
2009	22.21	22.25	21.76	20.01	16.48	12.74	12.49	15.14	15.05	16.91	18.45	19.56	213.05
2010	21.86	23.48	21.76	18.81	17.07	12.09	13.53	15.25	16.51	16.55	18.94	18.33	214.18

Climatic data of the study sites (2005 – 2011) Döhne

Monthly Rainfall (mm)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
2005	229.9	92.1	102.7	50.4	31	10.1	5.9	47.9	40.4	43.3	153.1	25.6	832.4
2006	38.8	383	112.6	223.9	154	10.6	2.9	93.6	45.9	173.9	66.1	97.5	1402.8
2007	75.3	73.2	98.4	47	14.4	21.8	22.2	51.3	54.6	171.2	20.4	101.4	751.2
2008	214.5	137.8	37.2	50.2	11.5	65.4	0.2	31.4	15.6	139.6	67.8	63.7	834.9
2009	76.8	65.1	21.8	25.9	31.1	21.2	18	15.5	17.4	117.7	20.5	65	496
2010	133.1	61	83.4	57.6	8.9	34.4	15.6	7.2	7	149.7	114.6	189.7	862.2
2011	235.1	69.5	146.2	71	54.9								

Temp ^{0}C

2005	18.53	19.26	18.21	16.54	15.27	12.63	13.98	12.92	15.01	16.36	16.15	16.19	191.05
2006	18.94	19.97	17.02	16.01	12.33	11.41	13.76	12.43	14.38	15.34	16.43	16.9	184.92
2007	19.62	19.55	17.19	17.02	12.85	12.71	12.42	13.4	15.21	14.55	15.8	18.16	188.48
2008	18.8	18.9	18.05	14.93	15.88	12.19	12.97	12.84	13.17	14.81	16.65	17.97	187.16
2009	18.61	18.99	18.71	17.75	14.96	12.29	12.42	13.72	13.84	14.83	16.24	16.63	188.99
2010	19.17	20.65	19.75	16.77	16.05	12.45	13.49	14.95	15.44	14.43	16.46	16.64	196.25
2011	19.13	20.52	19.26	14.89	15.16								

Appendix 2 Analysis of variance tables for seed propagation of wild watermelon (Chapter2)

A. Soil temp. ^{o}C

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	1.1697	0.5849	4.58		
Mulching	2	2.5850	1.2925	10.13	0.146	<.001
Plant_Population	3	0.2505	0.0835	0.65	0.168	0.589
Mulching.Plant_Population	6	0.8792	0.1465	1.15	0.292	0.368
Residual	22	2.8070	0.1276			
Total	35	7.6914				
CV%	1.5					

B. Volumetric water content mmH20

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	0.98162	0.49081	15.61		
Mulching	2	12.58753	6.29377	200.19	0.4833	<.001
Plant_Population	3	0.57338	0.19113	6.08	0.557	0.004
Mulching.Plant_Population	6	0.11077	0.01846	0.59	0.0965	0.737
Residual	22	0.69167	0.03144			
Total	35	14.94498				
CV%	3.3					

C. Number of vines per plant

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	0.3629	0.1815	0.27		
Mulching	2	0.7004	0.3502	0.52	0.335	0.601
Plant_Population	3	0.6224	0.2075	0.31	0.387	0.819
Mulching.Plant_Population	6	2.9174	0.4862	0.72	0.670	0.636
Residual	22	14.8038	0.6729			
Total	35	19.4069				
CV%	18.9					

D. Height (m)

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	0.10699	0.05350	0.59		
Mulching	2	0.33639	0.16820	1.85	0.123	0.181
Plant_Population	3	0.49346	0.16449	1.81	0.142	0.175
Mulching.Plant_Population	6	0.27425	0.04571	0.50	0.246	0.800
Residual	22	2.00162	0.09098			
Total	35	3.21272				
CV%	15.7					

E. Number of leaves/plant

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	293.8	146.9	0.46		
Mulching	2	1485.2	742.6	2.32	7.30	0.122
Plant_Population	3	2049.0	683.0	2.14	8.43	0.125
Mulching.Plant_Population	6	2231.7	372.0	1.16	14.60	0.361
Residual	22	7033.7	319.7			
Total	35	13093.5				
CV%	23.0					

F. Fruit number per plant

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	0.03972	0.01986	0.49		
Mulching	2	0.09606	0.04803	1.18	0.0823	0.326
Plant_Population	3	0.14853	0.04951	1.22	0.0951	0.327
Mulching.Plant_Population	6	0.07666	0.01278	0.31	0.1646	0.923
Residual	22	0.89443	0.04066			
Total	35	1.25539				
CV%	15.9					

G. Fruit number per ha

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	460.7	230.3	1.08		
Mulching	2	754.8	377.4	1.77	5.96	0.194
Plant_Population	3	15995.3	5331.8	24.99	6.89	<.001
Mulching.Plant_Population	6	787.5	131.3	0.62	11.93	0.716
Residual	22	4693.1	213.3			
Total	35	22691.4				
CV%	13.9					

H. Total yield **(kg/ha)**

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	3809.	1905.	0.78		
Mulching	2	3989.	1995.	0.81	20.20	0.456
Plant_Population	3	53848.	17949.	7.33	23.33	0.001
Mulching.Plant_Population	6	4471.	745.	0.30	40.41	0.928
Residual	22	53884.	2449			
Total	35	120002.				
CV%	30.4					

I. Fresh mass (kg)

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	0.1098	0.0549	0.38		
Mulching	2	0.0293	0.0147	0.10	0.1557	0.904
Plant_Population	3	0.3883	0.1294	0.89	0.1798	0.462
Mulching.Plant_Population	6	0.4535	0.0756	0.52	0.3114	0.787
Residual	22	3.1991	0.1454			
Total	35	4.1800				
CV%	24.7					

J. Dry fruit mass (kg)

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	0.01426	0.00713	0.59		
Mulching	2	0.03130	0.01565	1.29	0.0450	0.295
Plant_Population	3	0.01898	0.00633	0.52	0.0519	0.672
Mulching.Plant_Population	6	0.04032	0.00672	0.55	0.0899	0.762
Residual	22	0.26677	0.01213			
Total	35	0.37163				
CV%	30.0					

K. Fruit size distribution

a) Small_square_root

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	1.680	0.840	0.32		
Mulching	2	0.635	0.318	0.12	0.657	0.885
Plant_Population	3	4.706	1.569	0.61	0.758	0.618
Mulching.Plant_Population	6	10.217	1.703	0.66	1.313	0.684
Residual	22	56.909	2.587			
Total	35	74.148				
CV%	37.8					

b).Variate: Med_square_root

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	5.814	2.907	0.74		
Mulching	2	0.879	0.440	0.11	0.810	0.895
Plant_Population	3	5.879	1.960	0.50	0.935	0.688
Mulching.Plant_Population	6	14.317	2.386	0.61	1.620	0.723
Residual	22	86.640	3.938			
Total	35	113.529				
CV%	66.5					

Appendix 3 Market prices of pumpkins and watermelons (adapted from Abstracts of Agricultural Statistics and Trends in Agric Sector 2011)

A. Total tonnage for pumkins sold in markets per year from October to September (2008/9 – 2011).(Soource: Trends in Agricutural Sector,2011)

	2008/2009	**2009/2010**	**2010/2011**
Tons sold p/y	75 519	74 404	83 336
Av. R/ton	1454,57	1406,43	1577.09

B. Total tonnage for watermelons sold in markets per year from October to September (2008/9 – 2011). (Adapted from Abstracts of Agric Statistics, 2012)

	2008/2009	**2009/2010**	***2010/2011***
Tons sold p.y	40720	69001	*104 852*
Av. R/ton	1997	1232	*934*

C. Market prices of watermelon as per (Source: Market Prices for vegetables as at 02/05/2012).

COMMODITY	**SIZE**	**BLOEMFONTEIN**	**CAPE TOWN**	**DURBAN**
WATERMELON	LARGE/ 10 KG	-	-	-
	MEDIUM/ 6 KG	R 6, 29	-	R8, 00
	SMALL/ 3KG	R10, 00	-	-
	LARGE/ 50 KG CRATE	-	R500, 00	-
	MEDIUM/ 50 KG CRATE	-	R250, 00	-
	SMALL/ 50 KG CRATE	-	R 154, 55	-

D. Market prices of watermelon as per (Source: Market Prices for vegetables as at 14/05/2012).

COMMODITY	**SIZE**	**EAST LONDON MARKET**	**PORT ELIZABETH MARKET**	**KEI MARKET**
WATERMELON	LARGE/ 10 KG	R30.00	**-**	**-**

Appendix 4 Analysis of variance table for seedling propagation of wild watermelon (Chapter 3).

A. Soil Temp°C

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	0.16417	0.08209	2.66		
Mulching	2	1.13878	0.56939	18.44	0.0716	<.001
Plant_Population	3	0.13264	0.04421	1.43	0.0827	0.260
Mulching.Plant_Population	6	0.19024	0.03171	1.03	0.1432	0.434
Residual	22	0.67929	0.03088			
Total	35	2.30512				
CV%	0.9					

B. Soil moisture content (mmH20)

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	0.21901	0.10950	7.20		
Mulching	2	1.75829	0.87915	57.78	0.0504	<.001
Plant_Population	3	6.83068	2.27689	149.64	0.0581	<.001
Mulching.Plant_Population	6	0.24177	0.04029	2.65	0.1007	0.044
Residual	22	0.33476	0.01522			
Total	35	9.38450				
CV%	2.3					

C. Vine length (m)/height

Variate: Vine length (m)

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	0.90701	0.45350	7.68		
Mulching	2	0.09310	0.04655	0.79	0.0992	0.467
Plant_Population	3	0.26571	0.08857	1.50	0.1145	0.242
Mulching.Plant_Population	6	0.21392	0.03565	0.60	0.1984	0.724
Residual	22	1.29869	0.05903			
Total	35	2.77843				
CV%	14.9					

D. Vine number

Variate: Number of vine per plant

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	0.7504	0.3752	0.84		
Mulching	2	1.2893	0.6447	1.44	0.273	0.258
Plant_Population	3	1.9608	0.6536	1.46	0.315	0.252
Mulching.Plant_Population	6	4.5183	0.7531	1.69	0.546	0.172
Residual	22	9.8236	0.4465			
Total	35	18.3426				
CV%	14.3					

E. Leaf number per plant

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	1660.7	830.4	7.75		
Mulching	2	97.0	48.5	0.45	4.23	0.642
Plant_Population	3	740.8	246.9	2.30	4.88	0.105
Mulching.Plant_Population	6	1922.9	320.5	2.99	8.45	0.027
Residual	22	2358.0	107.2			
Total	35	6779.4				
CV%	16.2					

F. Fruit number per plant

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	0.01578	0.00789	0.23		
Mulching	2	0.10620	0.03540	1.05	0.0749	0.390
Plant_Population	3	0.00980	0.00490	0.15	0.0865	0.865
Mulching.Plant_Population	6	0.07854	0.01309	0.39	0.1498	0.878
Residual	22	0.74056	0.03366			
Total	35	0.95088				
CV%	15.1					

G. Fruit number per hectare

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	276.2	138.1	0.69		
Mulching	2	14096.2	4698.7	23.49	5.77	<.001
Plant_Population	3	69.2	34.6	0.17	6.67	0.842
Mulching.Plant_Population	6	524.1	87.4	0.44	11.55	0.846
Residual	22	4401.0	200.0			
Total	35	19366.8				
CV%	16.2					

H. Fresh mass (kg)

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	0.02967	0.01484	0.31		
Mulching	2	0.21041	0.07014	1.48	0.0889	0.247
Plant_Population	3	0.02907	0.01454	0.31	0.1026	0.739
Mulching.Plant_Population	6	0.25029	0.04171	0.88	0.1777	0.525
Residual	22	1.04224	0.04737			
Total	35	1.56168				
CV%	13.3					

I. Dry mass (kg)

Variate: Yield_kg_ha_square_root

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	0.023964	0.011982	2.60		
Mulching	2	0.004490	0.001497	0.32	0.0277	0.808
Plant_Population	3	0.006117	0.003058	0.66	0.0320	0.525
Mulching.Plant_Population	6	0.006787	0.001131	0.25	0.0555	0.956
Residual	22	0.101527	0.004615			
Total	35	0.142885				
CV%	19.2					

J. Total yield (kg)

Variate: Yield_kg_ha_square_root

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2010 stratum	2	209.1	104.5	0.13		
Mulching	2	31635.6	10545.2	12.91	11.67	<.001
Plant_Population	3	763.7	381.9	0.47	13.47	0.633
Mulching.Plant_Population	6	4269.7	711.6	0.87	23.33	0.531
Residual	22	17967.8	816.7			
Total	35	54845.9				
CV%	17.6					

K. Fruit size distribution

i).Variate: Small_square_root

Source of variation	d.f. (mv)	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2011 stratum	2	6.908	3.454	1.53		
Mulching	2	1.130	0.565	0.25	0.614	0.781
Plant_Population	3	22.910	7.637	3.37	0.709	0.037
Mulching.Plant_Population	6	17.985	2.997	1.32	1.228	0.288
Residual	22	49.789	2.263			
Total	35	98.722				
CV%	22.3					

ii).Variate: Med_square_root

Source of variation	d.f.	s.s.	m.s.	v.r.	s.e.d.	F pr.
Rep_2011 stratum	2	16.812	8.406	2.30		
Mulching	2	0.452	0.226	0.06	0.780	0.940
Plant_Population	3	22.673	7.558	2.07	0.900	0.133
Mulching.Plant_Population	6	34.499	5.750	1.58	1.560	0.201
Residual	22	80.279	3.649			
Total	35	154.715				
CV%	28.2					

L. ANOVA Table for Weed dry mass

Variate: Dry Total_Weight_

Source of variation	d.f.	s.e.d.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2		94.	47.	0.04	
Mulch	2	30.74	464.	232	0.18	0.840
Plant_polulation	3	35.50	23084	7695.	5.84	0.004
Mulch.Plant_polulation	6	61.48	7732.	1289.	0.98	0.464
Residual	22		29005.	1318		
Total	35		60378			

CV% 56.6

Appendix 5: Field trial layout

REP 1

1	2	3	4	5	6	7	8	9	10	11	12
B	**I**	**G**	**A**	**C**	**K**	**F**	**H**	**J**	**L**	**D**	**E**

REP 2

1	2	3	4	**5**	6	7	8	9	10	11	12
F	**K**	**L**	**E**	**I**	**B**	**J**	**D**	**A**	**H**	**C**	**G**

REP 3

1	2	3	4	5	6	7	8	9	10	11	12
E	**J**	**C**	**D**	**F**	**A**	**H**	**G**	**K**	**I**	**B**	**L**