بسم الله الرحمن الرحيم

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Genetic variability, Correlation and path analysis among some sesame (*Sesamum indicum)* Genotypes under irrigation system

التباين الوراثي ، والارتباط وتحليل المسار لبعض الطرز الوراثية لمحصول السمسم تحت ظروف الري

A Thesis Submitted to the Sudan University of Science and Technology in Partial fulfillment of the Requirements for the Degree of Master (M.Sc.) in Agronomy

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الآية

(وَهُوَ الَّذِي أَنْزَلَ مِنَ السَّمَاءِ مَاءً فَأَخْرَجْنَا بِهِ نَبَاتَ كُلِّ شَيْءٍ فَأَخْرَجْنَا مِنْهُ خَضِراً نُخْرِجُ مِنْهُ حَبّاً مُتَرَاكِباً وَمِنَ النَّخْلِ مِنْ طَلْعِهَا قِنْوَانٌ دَانِيَةٌ وَجَنَّاتٍ مِنْ أَعْنَابٍ وَالزَّيْتُونَ وَالرُّمَّانَ مُشْتَبِهاً وَغَيْرَ مُتَشَابِهٍ انْظُرُوا إِلَى ثَمَرِهِ إِذَا أَثْمَرَ وَيَنْعِهِ إِنَّ فِي ذَلِكُمْ لَآياتٍ لِقَوْمٍ يُؤْمِنُونَ)

صدق الله العظيم

(الأنعام:99)

Dedication

This thesis is dedicated to my father and my mother, who taught me that the best kind of knowledge to have is the one learned for its own sake. They also taught me that even the largest task can be accomplished if it done one step at a time.

I would like to dedicate the thesis to my sisters and brothers, without their encouragement, I would not have finished is degree.

For my family, who offered me unconditional love and support throughout the course of this thesis

To my friends who always ready to land a hand.

And to everybody spend in love and encourage me………….

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LIST OF ABBERRVATIONS

%	Percent
ºC	Degree centigrade
cm	Centimeter
ppm	part per million
g	Gram
mg	Milligram
L	Litre
SE	Standard Error
h	Hours
ha	Hectare
CV	Coefficient of Variation
et al	and others
No.	Number

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Abstract

Field experiment was conducted during season 2015/2016 on the demonstration farm of the College of Agriculture Studies, Sudan University of Science and Technology at Shambat to evaluate of ten sesame genotypes under irrigation system and to determine the best genotypes suitable for cultivation and to study the correlation and path analysis. . The experiment was arranged in a Randomized Complete Block Design (RCBD), with three replicates. Parameters recorded included plant height, number of branches/plant, number of capsules/plant, number of seeds/capsules, 1000 seed weight, seed weight and dry weight. The results showed highly significant difference in plant height, number of branches and seed yield between the sesame genotypes. However, the analysis of variance showed that non-significant differences in number of capsules per plant, number of seeds per capsules,1000 seed weight and dry weight between sesame genotype studies. Alsodona genotype sustained the tallest plant height (162.5), while, Alradom, Bash and Tailandi genotypes displayed the shortest plant height (110.0-113.2 cm). The highest number of branches was recorded for Alradom genotype (7.7); however, Bash displayed the lowest number of branches. Abraway genotype displayed the highest number of capsules (62.5 capsules), however, bash and Tailandi displayed the lowest number of capsules (35.2 capsules/plant). The results showed that Carawy produced the highest number of seeds per capsules (64.6 seeds), while Alsodona produced the lowest number of seeds capsules (50.3 seeds). Varity 17 genotype significantly gave the highest thousand seed weight (4.6 g). Alsodona and genotype gave the highest seed yield (21.1 t/ha), while Bash, Alsodona, Soliamani and Alradom genotypes displayed the lowest seed yield (11.4-12.8 t/ha), as compared to others genotypes. Alsodona, Huria15, Carawy and kenana genotypes gave the highest dry weight (0.24-0.28g), while Bash displayed the lowest dry weight (0.12g). Number of capsules and dry weight showed the highest significant positive simple liner correlation with grain yield in combined, whereas number of branches showed the highest significant negative correlation with grain yield in combined. Number of capsules showed the highest direct effect, whereas the highest indirect effect exhibited for number of capsules in path analysis.

الملخــــص

أجريت تجربة حقلية خلال موسم 2016/2015م بالمزرعة التجريبية بكلية الدراسات الزراعية –شمبات وذلك لتقيم عشرة طرز وراثية لمحصول السمسم تحت ظروف الري وتحديد أفضل طرز وراثية يمكن زراعتها ودراسة الأرتباط وتحليل المسار. تم تصميم التجربة علي نظام القطاعات العشوائية الكاملة في ثلاثة مكررات. تضمنت القياسات التي تم رصدها طول النبات، عدد الخلف في النبات، عدد الكبسولات في النبات، عدد البذور في الكبسولة، وزن الألف بذرة، إنتاجية البذور والوزن الجاف للنبات. أوضحت النتائج وجود فروقات معنوية عالية في طول النبات، عدد الخلف وإنتاجية البذور بين الأصناف. بينما أظهر جدول تحليل التباين عدم وجود فروقات معنوية في عدد الكبسولات في النبات، عدد البذور في الكبسولة، وزن الألف بذرة، والوزن الجاف بين الطرز الوراثية للسمسم التي تمت دراستها. أعطي طرز وراثي السودنة أعلي طول نبات (162.5)، بينما أعطت طرز وراثي الردوم، باش وتايلندي أقل طول نبات (100–113.5سم). أعلي عدد خلف تم تسجيله في طرز وراثي الردوم (7.7). بينما أعطي طرز وراثي باش أقل عدد للخلف. أعطي الصنف عبراوي أعلي عدد كبسولات (62.5 كبسولة/النبات)، بينما أعطت الأصناف باش وتايلندي أقل عدد كبسولات (35.2 كبسولة /النبات)، وذلك مقارنة ببقية الطرز الوراثية. أظهرت النتائج بأن طرز وراثي كاراوي أنتج أعلي عدد من البذور في الكبسولة (64.6 بذرة)، بينما أنتج طرز وراثي السودنة أقل عدد من البذور (50.3 بذرة). أعطي طرز وراثي فاريتي 17 معنوياً أعلي وزن الف بذرة (4.6 جرام)، بينما أعطت طرز وراثية كلا من السودانة والردوم أقل وزن الف بذرة (3.2 جرام). أعطي طرز وراثي كنانة أعلي إنتاج بذور (21.2 طن/هكتار)، بينما أعطت الطرز الوراثية باش، السودانة، سوليماني والردوم أقل أنتاجية بذور (11.5–12.8 طن/هكتار)، وذلك مقارنة ببقية الطرز الواثية. أعطت الأصناف السودنة، حرية 15، كاراوي وكنانة أعلي وزن جاف للنبات (0.24–0.28 جرام) بينما أعطي طرز وراثي باش أقل وزن جاف للنبات (0.12 جرام). اظهرت الدراسة ان أنتاجية عدد الكبسولات والوزن الجاف اظهر اعلي معنوية موجبة للأرتباط الخطي البسيط مع انتاجية الحبوب وبينما عدد الافرع اظهر اعلي معنوية سالبة مع انتاجية الحبوب. اظهر عدد الكبسولات اعلي تأثير مباشر بينما اعلي تأثير غير مباشر كان لعدد الكبسولات في تحليل المسار.

CHAPTER ONE

Introduction

Sesame (*Sesamum indicum L.*) belongs to family Pedaliaceae, is considered as one of the most ancient oilseeds crop known to mankind, it is also known as bennseed in Africa and sim-sim in East Africa. The genus has many species, and most of them are wild. Most wild species of the genus *Sesamum* are native to sub-Saharan Africa. *S. indicum,* the cultivated type originated in India (Bedigian, 2010; Zohary and Hopf, 2012).

It is extensively cultivated in the tropics and temperate zone of the world (Biabani and Pakniyat, 2008). India, China, Burma, Sudan and Mexico are the largest producers (Bennett *et al*., 2003). According to FAO (2008), the global cultivated area of sesame was about 7.4 million hectares producing about 3.4 million metric tons which makes it the fifth most important oil seed crop on an area basis worldwide. FAO (2008) reported that, the Sudan grows about 20.12% (1.48 million hectare) of the world cultivated area, and contributes about 9.24% (0.32 million metric tons) of the total production.

Sesame is considered to have both nutritional and medicinal values. It is grown mainly for its seeds that contain approximately35- 60% oil (El Khier *et al*., 2008; Alyemeni *et al*., 2011) and 25% protein (Burden, 2005).The seeds have many colors like red, white, black and yellow, depending upon the variety. Sesame seeds have high nutritive value and are used in numerous cuisines all over the world. The presence of some antioxidant (sesamum, sesamolin or sesamol) makes the oil to be one of the most stable vegetable oils in the world. The residue left after the extraction of oil is known as the oil seed cake which is used as livestock feed.

Sesame is one of the important cash crops in the Sudan and is grown under rain-fed conditions by traditional or mechanized farming, semi- commercial and commercial farmers. It is grown mainly in the sandy soils of Northern Kordofan and central clay plain, especially in Al-Gedarif and Al-Damazin areas. It is also grown in Southern Kordofan and Southern Darfur and on a small scale in the southern region (Khidir, 2003; Omer and Ali, 2003). In the Sudan, sesame is one of the important oil crops, coming third in production area after sorghum and millet. It draws its importance from its use as a food crop, a raw material for industry, feed for livestock and as a leading export crop (Abdel- Rahman, 2008).

Sudan is the third largest producer of sesame in the world, after India and China. Nevertheless, it is considered the main world exporter of sesame seeds (Maryoud *et al*., 2008). Sudan ranks second in the volume of sesame exports and accounts for 80% and 40% of all cultivated sesame area in the Arab world and African continent, respectively (Abdalla and Abdel Nour, 2001). In the recent past the country witnessed an expansion in area planted to sesame. The area under sesame cultivation is currently estimated at about 4,938,238 feddans. Sesame seed production in Sudan is estimated at about 450,000 MTs and is grown under rain-fed conditions by subsistence, semi- commercial and commercial farmers. It contributes to Sudan's export trade and earnings. This cultivation range extending from the semi-arid tropics to sub-tropic temperate regions has lead to a wide diversity of genotypes (Söğüt, 2008).The main differences in the yield variation in terms of morphological properties and chemical composition of sesame cultivars have been attributed to the lack of new cultivars for high yield, early maturity, non-shattering and wide adaptation (Baydar *et al*., (2005). In addition to differences in morphological properties, protein content, oil content and fatty acid compositions may vary considerably between genotypes under different environmental conditions (Sogut, 2008). There are three wild relatives of sesame recognized in Sudan including *S. alatum, S. latifolium* and *S. anguistifolium*. The existing wide variability in cultivated landraces and the wide spread of wild types makes Sudan an important location for sesame genetic diversity. Collection efforts between 1999 and 2008 have resulted in more than 300 accessions from areas in eastern, western and central Sudan including both cultivated and wild material with different characteristics especially seed color (Nahar, 2009). Genotypes vary in their adaptability to different growing conditions. The ability of sesame yield is determined by different yield components, all of them are substantially influenced by environmental conditions and agronomic practices (Caliscan, 2004).

The objectives of this study are:

1- Evaluate the performance of some sesame genotypes under irrigation condition.

2- To the study the interrelationship between studied traits.

3- Study the path coefficient analysis to determine the direct and indirect effects among studied traits.

CHAPTER TWO

Literature Review

2-1: General

Sesame is one of the world most important and oldest known oil seed crops. Its cultivation dated as far as 1500 BC in the Middle East, Asia and Africa (Ali *et al*., 2007). Sesame is a survivor crop. For 5,000 years it has been planted by subsistence farmers in areas that will not support the growth of other crops or under very difficult conditions with drought and/or high heat (Langham, 2007).

It took the 9th position among the top 13 oilseed crops which make up 90% of the world production of edible oil (Adeola *et al*., 2010). The sesame crop is adapted and cultivated both in the tropic and temperate zones of the world (Biabani and Pakniyat, 2008).

2-2: Botanical description

S. indicum is an erect annual plant that can grow to a height of 1.0 to 2.0 meters depending on the cultivar and the growing conditions (Bennett *et al*., 2003). However, varieties that are 1.0 to 1.4 m high are more common (Ashri, 2007). Sesame is deep-rooted, which can reach up to 990 cm in length and will search nutrient from below most crop zones (Langham *et al*., 2008). The long taproot contains many lateral roots. In the early maturing varieties, the root system is poorly developed, but late maturing varieties have a well-developed root system (Singh, 1978). Its erect stem is usually square. It bears elongated oval leaves on a stem which can be branched or un- branched, depending on the variety. The stem is covered with short, soft hairs. Sesame is characterized by opposite leaves and bell-shaped flower. The plant bears its flowers in the axils of the leaves. The color of the corolla varies from white to purple (Singh, 1976). The fruiting shape of sesame is a capsule, often called pods. They have divided sections like a cotton boll. Varieties have a single capsule or triple capsules per leaf axil (Langham *et al.,* 2008). The seed is produced in capsules with about 70 seeds per capsule. Sesame seed can be black, brown or white in color and contains about 50% oil and 20% protein (Bennett *et al*., 2003). The blossoming and ripening phases take place over several weeks, starting at the bottom of the plant and progressing upwards (Augstburger *et al*., 2002). Physiological maturity normally occurs 95-110 days after planting for early types and up to 150 days for late types. Physiological maturity is when 75% of the capsules on the main stem have mature seeds or when three-fourth of the stem turns yellow (Geremew *et al*., 2012).

2-3: Climatic conditions:

Sesame is an important oilseed crop successfully grown in Tropical and sub-tropical climates from 25°N to 25°S (Ahmed and Ahmed, 2012). It has a deep tap root system and ability to set seeds under high temperature that enable it to grow well in different agro ecological zones, including the arid and semi-arid zones (Iman *et al*., 2011).Generally, the plant will have a better chance of survival when it is grown in hotter than optimal temperatures rather than lower optimal temperatures (Langham *et al*., 2008). Sesame needs a constant high temperature, the optimum range for growth, blossoms and fruit ripeness is 26-30°C (Augstburger *et al*., 2002). Low temperature at flowering can result in the production of sterile pollen or premature flower fall (WARC, 2009). Pollination and the formation of capsules are inhibited during heat wave periods above 40°C. Depending on the climate, sesame can be cultivated at altitudes up to 1600 m (Augstburger *et al.*, 2002). Once established, sesame is capable of withstanding a higher degree of water stress than any other cultivated plants. However, it requires adequate moisture during germination and early growth for reasonable yields (WARC, 2009). Sesame is highly susceptible to water-logging and can therefore only thrive during moderate rainfall or when irrigation is carefully controlled in drier regions. Due to its tap roots, the plant is highly resistant to drought and can provide good harvests even when only stored soil water is available (Augstburger *et al.*, 2002). Sesame is basically a short-day plant and with a ten hour day, will normally flower in forty-two and forty-five days, but many varieties have become locally adapted to various light period (Weiss, 1983). Sesame needs long periods of sunshine and is generally a short-day plant whereby varieties exist which are unaffected by the length of the day. Sesame is sensitive to strong winds when the main stem is fully grown. Tall varieties should not be planted in regions, which have strong winds during the harvesting season (Augstburger *et al.*, 2002).

2-4: Soils

Sesame grown well on a wide variety of soil types, from sand to clay, but thrives best on those, which are moderately fertile, and free draining with pH 5.5-8.0 (Weiss, 1983). Sesame has moderate salt tolerance (Bahrami and Razmjoo, 2012), but will not grow under flooded conditions. Sesame grows better in sandy than in heavy soils when irrigated, or during summer rain. This is due to its sensitivity to high soil moisture contents. Heavy water-logged soils as well as soils with high salt contents are not suitable. Salt contents which would hardly affect cotton or safflower can kill off sesame plants (Augstburger *et al.*, 2002). Where soil is of lower fertility, heavier applications of commercial fertilizer are required for satisfactory production.

2-5: Sowing Date:

Sesame yield is highly variable depending upon the growing environment, cultural practices and cultivars. Planting time of sesame is the most critical phase of its management. Major factors determining time of planting are availability of moisture, length of the rainy season and temperature. In rain grown sesame, planting dates virtually depend on on-set of rainfall and length of growing season. In dry areas with short rainy months, it is advisable to sow immediately after the first rains. But in areas with long growing seasons, time of planting should be adjusted with the time of harvesting in such a way that the crop gets matured when the rain stops (Hegde and Sudhakara Babu, 2002). One of the main factors limiting sesame production in the Sudan is the planting dates, which are between 15 June and 15 July, depending on rainfall. Osman (1985) showed that the optimum sowing date extends from the end of June to the first week of July. Studies on sesame sowing dates, in Sudan, showed that sowing on 15th of June, July and August attained 536, 346 and 292 kg/ha grain yield, respectively (El Mahdi *et al*., 2007). El Mahdi *et al*. (2007) found that delaying the sowing date decreased the average seed yield and also decreased number of capsules per plant and 1000-seed weight.

2-6: Seed rate, plant spacing and Plant densities:

Sesame is almost entirely cultivated under rain-fed in the Sudan. Poor management practices especially the practice of low seed rate as well as traditional cultivars are the main yield limiting factors in sesame farms of sandy dunes in north kordofan of Sudan. El Naim *et al*. (2012) found that seed rate of 1.5 and 2.0 Kg ha^{-1} were optimum for sesame cultivation under rain fed conditions in sandy dunes of North Kordofan state, Sudan.

Row spacing of 25–75 cm is recommended for sesame crop in different countries (Hedge, 2004).The establishment of an adequate plant density is critical for utilization of available growth factors such as water, light, nutrients and carbon-dioxide and to maximize grain yield. Too wide spacing leads to low plant density per unit area and reduces ground cover, whereas too narrow spacing is related to intense competition between plants for growth factors (Singh *et al*., 2004). On the other hand, the variation in plant density has been related to the variation in the number of capsules per plant, seed yield per plant and 1000-seed weight (Rahnama and Bakhshandeh, 2006), and plant height, number of branches per plant and seed yield (Ngala *et al*., 2013). Previous studies indicated that sesame cultivars are variable in their response to plant density. El Naim *et al*. (2010) found that increased plant population had the general tendency to increase seed yield (t/ha) and also showed that plant populations of approximately 166,666 and 249,999 plants ha^{-1} were optimum for sesame cultivation under rain fed conditions in North Kordofan state, Sudan.

2-7: Sesame cultivars

There are many varieties and strains, which are known is sesame-growing countries, which differ considerably in size, form, and color of flowers, seed size, color and composition of seeds. Non-shattering cultivars are now being developed (Weiss, 1983). Several sesame varieties are used in the world market. There are including local varieties and commercial varieties. However, the cultivation of improved varieties is limited due to insufficient variety information. The farmers continue to grow local varieties with low yields (Duc Pham *et al*., 2010). Higher productivity in sesame crop can be achieved through a combination of an ideal variety associated with proper environment and appropriate agronomic practices. There is a great deal of evidence to show that sesame varieties respond differently to agronomic practices (Hedge, 2004). A large amount of variations in days to flower initiation, plant growth, number of branches and yield components such as number of capsules, number of seeds per capsule, seed yield per plant between different sesame varieties (Negasa, 2014). Sesame varieties varied with respect to days to flower initiation and days to 50% flowering. Flowering starts from 35 to 45 days after planting and continues for

75 to 85 days for early types and with some varieties lasting 150 days even to mature (Geremew *et al*., 2012).

In Sudan, generally, local varieties Hirihri (early maturing), Jabarouk (medium) and Baladi or Jaball (late maturing) are cultivated in Kordofan. Improved seed varieties are cultivated in limited area in Mechanized Agricultural farms at Gadaref and Damazin due to un-availability of improved seed and limited extension (Khidir, 1997). Some varieties are released in the last 20 years ago, with variable seed colour are, (Zirra 1,3,7,9 and Kenana-1) with white-seeded varieties and (Huria 1, 31 and 49) as brown-seeded varieties. Another white-seeded variety namely Kenana 2 was released in 1991, which now dominates most of the central rain-lands (Ahmed, 1998a). Lately two varieties were released namely Khidir and Promo. Khidir for production in high rainfall areas with vigorous growth, dark green color **,** highly branching, medium maturity (90-105 days), with white seed, high yielding (750-1000 kg/ha), adapted to a wide range of environment**.** Average 1000 seed weight of 3.24 g, seed oil and protein contents of 49.0 and 30.6%, respectively. Moreover, sesame cultivar Promo for production in areas of high and low rainfall, has vigorous growth with light green color, medium branching tall (150 cm), white seeded, medium yield (600-800 kg/ha). It has a 1000 seed weight of 3.42 g and seed oil and protein contents of 48.0 and 31.0% respectively (Ahmed, 1998b).

2-8: Sesame fertilization:

Sesame responds but poorly to applications of fertilizers. The application of fertilizers must be related to the growth stage of the plant, plant population, soil fertility and amount of soil moisture available. Sesame's nitrogen requirement can be fulfilled through organic sources, such as leguminous cover crops or animal manure. Phosphorous and potassium needs are not known exactly. If soils are acidic, pH should be brought up through liming (Geremew *et al*., 2012).

In Sudan, Osman (1986) reported that application of nitrogen or phosphorous had no significant effect on all sesame parameters. However, Osman (1993) found that grain yield and yield parameters of sesame were significantly enhanced by the application of 40 kg N ha^{-1}. Ashfaq *et al.* (2001) found that the highest seed yield and yield components were obtained with 20 and 40 kg ha^{-1} nitrogen and phosphorous rates, respectively. Mankar *et al.* (1995) showed that phosphorous application at the rate of 22 kg P ha^{-1} significantly enhanced seed yield, seed oil content and seed protein content of sesame. Olowe and Busari (2000) found that application of 60 kg N ha^{-1} and 13.2 kg P ha^{-1} produced significantly the highest number of capsules per plant, branches per plant, capsule weight per plant and grain yield per hectare. Hossein *et al*. (2007) recorded the highest sesame seed yield with the application of 60 kg N ha^{-1}. Application of 44 kg N ha^{-1} resulted in a marked increase in seed yield and yield components of sesame variety Shuak under conditions of Northern Sudan (El Mahadi, 2008).

2-9: Irrigation:

Crop production is a function of water, nutrient, climate and soil environment. Provided that all other requirement are satisfactory for proper growth and production, rainfall rarely meets the time with required amount of water application for plant growth. As a result, average yield of agricultural crops under rain-fed agriculture is low when compared to irrigated agriculture. The performance of rain-fed agricultural production and productivity remained low and stable for most of the years (Tilahun *et al*., 2000).

Sesame crop requires only 500-650 mm of rainfall per annum but it could be sensitive to drought during its vegetative stage (Boureima *et al*., 2011). Sesame is normally a rainfall crop but when there is deficiency of moisture in the soil it is better to irrigate the crop. It is affected by heavy application of water that results in water standing at the base of the plant, therefore, the crop will shown stress in the hot afternoon, but it is when the sesame shows stress in the morning that irrigation is needed. The small amount and short watering interval has been found to give higher yields than a larger application at longer intervals. A high application rate of water tends to reduce both seed weight and oil content. Rains or irrigations after the ripening phase do not increase yield and yield components of sesame, but may delay harvesting time (Kostrinsky, 1959). Growth can greatly be reduced by water stress, and even favorable moisture conditions at subsequent growth stages would not alleviate this check in crop growth (Vyas *et al*., 1983). The yield of sesame varies with season, method of cultivation and variety and ranges from a few hundred to 3000 kg/ha in different countries (Hedge, 2004). Langham (2008) reported that in rain fed conditions, the final plant heights are lower than under irrigation conditions, but the pattern of very slow growth followed by fast growth during the reproductive phase exists under all conditions. Lazim (1973), in experiment conducted in shambat, using irrigation quantity of 600mm applied at 10-days interval, produced yield ranging from (162-362kg/ha). Nielson and Nelson (1998) found that water stress during the vegetative growth stage produced the shortest plants with least leaf area.

2-10: Genetic variability:

The determination of genetic variability and its partitioning into various components is essential for understanding the genetic nature of yield and its components. Yield is a complex quantitative character controlled by many genes interacting with the environment and is the product of many factors called yield components. Selection of parents based on yield alone is often misleading. Hence, the knowledge about relationship between yield and its contributing characters is needed for an efficient selection strategy for the plant breeders to evolve an economic variety. The information about phenotypic and genotypic interactions of various economic traits is the immense importance to a plant breeder for the selection and breeding of different genotypes with increasing yield potential (Amin, 1979). The progress in breeding for yield and its contributing characters of any crop is polygenic ally controlled, environmentally influenced and determined by the magnitude and nature of their genetic variability (Fisher, 1981). It is very difficult to judge whether observed variability is highly heritable or not. Moreover, knowledge of heritability is essential for selection based improvement, as it indicates the extent of transmissibility of a character into future generations. Sabesan *et al. (*2009).

2-11: Correlation

Correlation analysis can be use to understand the relationships existing between yield and yield components associated with it (Mukthar *et al.*, 2011). This technique measures the degree of relationship existing between various plant characteristics; and as well predicts the plant characters that can be selected for sesame improvement with respect to associated complex character-yield (Gelalcha and Hanchinal, 2013). In this regard, Azeez and Morakinyo (2011) reported that leaf nodes per plant, number of pods per plant, number of pods per main stem, number of seeds per pod, 100-seed weight, and number of seeds per plant were positively correlated with seed yield of sesame.

2-12: Path Coefficient analysis:

Path analysis is a technique use to determine the direct influence of one variable on another; and is also use to separate the correlation coefficient into direct effect (path coefficient) and indirect effects (effects exerted through other independent variables) (Azeez and Morakinyo, 2011). Furthermore, Gelalcha and Hanchinal (2013) noted that the concept of path analysis also measures the relative importance of causal factors which provide information for effective selection during crop improvement program.

CHAPTER THREE

Materials and Methods

3-1: Experimental site:

A field experiment was undertaken in the demonstration farm of the College of Agricultural Studies, Sudan University of Science and Technology at Shambat, Khartoum North, during season 2015-2016 To study the genetic variability, correlation and path analysis among sesame genotype under irrigation system. Shambat is located at latitude 32º35ºE, longitude 15º31ºN, and altitude 288m above sea level, within the semi-desert region (Adam, 2002) (Appendix 1). The soil of the site is described by Abdelgadir (2010) as clay soil with pH 8.2 (Appendix 2).

3-2: Plant material:

Sesame (*Sesamum indicum L.*) cultivars namely Alradom, Abraway, Bash, Huria15, Alsodana, Carawy, Solimani, Kenana, Tailandi and Varity15 were obtained from the Agricultural Research Corporation (ARC).

3-3: Methods:

3-3-1: Land preparation:

The land was ploughed, harrowed, leveled, ridged and divided into plots. The plot size was 9 m^2 (3×3m). Each plot consists of four ridges, 60 cm apart and 3 m long.

3-3-2: Cultural practices:

Five seeds per hole were sown in the top of the ridge early August. The spacing between holes was 15 cm, sowing was done manually. Land was immediately irrigated and subsequent irrigation was made every 7-10 days till the end of season. Sesame seedlings were thinned to two plants in each hole one week after sowing. Hand weeding was done manually four times during the growing season. The combination of insecticides Tricel and Hitcel were applied to control the heavy infesta.tion of Mealy bugs. The experiment was arranged in Randomized Complete Block Design (RCBD) with three replicates.

3.4: Data collected:

3-4-1: Growth parameters

Five plants were randomly selected from each plot, and then, the mean of these plants following parameters were recorded

3-4-1-1: Plant height (cm):

Plant height was measured from the ground level to the tip of the plant.

3-4-1-2: Number of branches per plant:

Number of branches was determined by counting the number of primary reproductive branches.

3-4-2: Yield components:

At the maturity, five plants were selected randomly from each plot and the following parameters were recorded.

3-4-2-1: Number of capsules per plant:

This was determined by counting the number of capsules on the 5 sampled plants in each plot at harvest and the mean calculated and recorded.

3-4-2-2. Number of seeds per capsule:

A random sample of 10 capsules was taken before threshing from five plants in shaking the inverted bundles a few times until all the seeds dropped from the each plot to determine the number of seeds per capsule. Threshing was done by capsules and finally the seeds were sieved and then counted.

3-4-2-3: 1000 seed weight (g):

Seeds weight was estimated by counting 1000-seed randomly from each plot three times, and then weighed using a sensitive balance.

3-4-2-4: Seed yield (kg/ha):

Seed yield was determined by harvesting all capsules in the plants of an area of one meter square. The capsules were dried, threshed and weighed to obtain seed yield as (kg/ha).

3-4-2-5: Dry weight (g):

The total above-soil dry weight of five randomly plants selected per each plot was recorded. The five plants were harvested, oven-dried at 70 C° for 48 hours.

3-5: Correlation:

The Pearson correlation coefficient is used to measure the strength of a linear association between two variables, where the value r = 1 means a perfect positive correlation and the value r = -1 means a perfect negative correlation. So, for example, you could use this test to find out whether people's height and weight are correlated (they will be - the taller people are, the heavier they're likely to be).

Equation:

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

3-6: Path analysis:

Path coefficient analysis following equations:

$P_1 + r_{12}P_2 + r_{13}P_3 = r_{14}$

$r_{12} + P2 + r_{23}P_3 = r_{24}$

$r_{13}P_1 + r_{23}P_2 + P_3 = r_{34}$

Where: P1, P2and P3 are path coefficients measures direct contribution of growth characters yield

r12...r34 are coefficients of correlations measures mutual association between two characters.

3-7: Statistical analysis:

The collected data was subjected analyzed to Analysis of variance (ANOVA) using Statistical Analysis System software (Statistix 8, version 2(UK). The means were separated using Least Significance Differences (LSD) at 5%

CHAPTER FOUR

Results

4-1: Growth parameters:

4-1-1: Plant height (cm):

The results showed highly significant differences (P<0.01) for plant height between the sesame genotypes (Appendix3). The mean of plant height of the genotypes were ranged between 110- 162.5 cm. Genotypes Alsodona sustained the tallest plant height (162.5cm), followed by Carawy, Abraway, Soliamani, and Varity17 displayed 141.7, 140.8, 140.5 and 134.3 cm plant height, respectively (Table 4.1). Kenana scored 126.2 cm height. However, Alradom, Bash and Tailandi genotypes displayed the shortest and comparable plant height (110.0-113.2 cm) (Table 4.1).

Table 4.1: Plant height of sesame genotypes:

Sesame genotypes	Plant height (cm)
Alradom	113.2 ^{c}
Abraway	140.8 ^{b}
Bash	110.8 ^{c}
Huria15	138.3 ^{b}
Alsodona	162.5 ^{a}
Carawy	141.7 ^{b}
Kenana	126.3 ^{bc}
Soliamani	140.8 ^{b}
Tailandi	110.0 ^{c}
Varity17	134.3 ^{b}
SE±	**9.41**
LSD	**19.77**
CV%	**8.74**

Means within a column followed by the same letter(s) are not significantly different according to LSD-Test at 5%.

4-1-2: Number of branches:

The results were showed a highly significant difference (P< 0.01) in number of branches per plant between the sesame genotypes (Appendix 4). The highest number of branches was recorded for Alradom genotype (7.7), followed by descending order by Abraway (6.3), Kenana (5.9), Soliamani (5.8) and Alsodona (5.2). The lowest number of branches (0.4) was recorded by Bash genotype(Table 4.2).

Table 4. 2: Number of branches of sesame genotypes:

Sesame genotypes	Number of branches/plant
Alradom	7.7 [a]
Abraway	6.3 [ab]
Bash	0.4 [d]
Huria15	4.4 [bc]
Alsodona	5.2 [ab]
Carawy	4.5 [b]
Kenana	5.9 [ab]
Soliamani	5.8 [ab]
Tailandi	1.7 [cd]
Varity17	4.6 [b]
SE±	**1.3**
LSD	**2.7**
CV%	**34.5**

Means within a column followed by the same letter (s) are not significantly different according to LSD-Test at 5%.

4-2: Yield parameters

4-2-1: Number of capsules per plant:

Analysis of variance was showed that non-significant differences (P<0.05) in number of capsules per plant between the sesame genotypes (Appendix 5). Among the ten genotypes tested, Abraway genotype displayed the highest number of capsules (62.5), but not significantly, in comparison to other genotypes (Table 4.3). Number of capsules per plant in Kenana and Carawy was

58.2 and 55.4, respectively. Alsodona and Huria15 sustained comparable number of capsules (49.0), followed by descending order by Varity17 (44.3), Soliamani (43.6) and Alradom (41.5). However, bash and Tailandi displayed the lowest number of capsules (35.2 capsules/plant), in comparison to other genotypes (Table 4.3). The observed differences between genotypes were not significant.

Table 4.3: Number of capsules of sesame genotypes:

Sesame genotypes	Number of capsules/plant
Alradom	41.5 [a]
Abraway	62.5 [a]
Bash	35.2 [a]
Huria15	49.6 [a]
Alsodona	49.0 [a]
Carawy	55.4 [a]
Kenana	58.2 [a]
Soliamani	43.6 [a]
Tailandi	35.0 [a]
Varity17	44.3 [a]
SE±	**14.4**
LSD	**30.4**
CV%	**37.3**

Means within a column followed by the same letter(s) are not significantly different according to LSD-Test at 5%.

4-2-2: Number of seeds per capsules:

The results of analysis of variance was showed non- significant differences in number of seeds per capsule between sesame genotypes tested (Appendix 6). The mean number of seeds per capsule of the sesame genotypes range between 50.3 and 64.6 seed. Carawy produced the highest number of seeds per capsule (64.6), while Alsodona produced the lowest number of seeds capsule (50.3), in comparison to the other sesame genotypes (Table 4.4). Number of seeds per capsule was 62.0, 60.0, 60.3, 59.0 and 58.7 on, Varity17, Bash, Soliamani, Huria15 and Alradom, respectively (Table 4.4).

Table 4.4: Number of seeds per capsules of sesame genotypes:

Sesame genotypes	Number of seeds/ capsules
Alradom	58.6 [a]
Abraway	52.3 [a]
Bash	60.3 [a]
Huria15	59.0 [a]
Alsodona	50.3 [a]
Carawy	64.6 [a]
Kenana	54.7 [a]
Soliamani	60.1 [a]
Tailandi	52.6 [a]
Varity17	62.0 [a]
SE±	**9.2**
LSD	**19.4**
CV%	**19.7**

Means within a column followed by the same letter(s) are not significantly different according to LSD-Test at 5%.

4-2-3:1000 seeds weight:

The weight of thousand seeds was not significantly ($P<0.05$) different with the sesame genotypes (Appendix 7). The mean of 1000 seeds weight of the genotypes range between 3.2 to 4.6 g. Varity 17 genotype significantly gave the highest thousand seed weight (4.6 g), as compared to other genotypes, followed by Tailandi and Kenana, displayed 3.7 and 3.6 g, respectively (Table 4.5). Alsodona and Alradom genotypes exhibited comparable lowest seeds weight (3.2 g). The average thousand seed weight on genotypes Abraway, Bash, Huria15, Carawy and Soliamani was 3.3g - 3.5 g, and the observed difference between genotypes was not significant (Table 4.5).

Table 4.5. 1000 seeds weight of sesame genotypes:

Sesame genotypes	1000 seeds weight (g)
Alradom	3.2 [a]
Abraway	3.3 [ab]
Bash	3.5 [ab]
Huria15	3.4 [ab]
Alsodona	3.2 [a]
Carawy	3.4 [ab]
Kenana	3.6 [ab]
Soliamani	3.4 [ab]
Tailandi	3.7 [b]
Varity17	4.6 [b]
SE±	**0.5**
LSD	**1.2**
CV%	**20.51**

Means within a column followed by the same letter(s) are not significantly different according to LSD-Test at 5%.

4-2-4: Yield (kg/ha):

The obtained results were show on that there were a significant differences in sesame seed yield (ton/ha) between the sesame genotypes (Appendix 8). Among the ten sesame genotypes, Kenana gave the highest seed yield (21.1 t/ha), followed by genotype Carawy (19.4 t/ha), while genotype Alradom gave the lowest seed yield (11.4 t/ha), as compared to other genotypes (Table 4.6). Bash, Alsodona and Soliamani displayed similar seed yield (12.4-12.8 t/ha). Seed yield in Varity17, Abraway, Huria15 and Tailandi were 14.6, 16.3, 16.6 and 16.8 t/ha, respectively (Table 4.6).

4-1-5: Dry weight:

Analysis of variance was showed that there were non-significant differences ($P < 0.05$) in sesame dry weight between the various genotypes (Appendix 9). Alsodona, Huria15, Carawy and Kenana genotypes gave the highest and comparable dry weight (0.24-0.28g), while Bash displayed the lowest dry weight (0.12g), in comparison to othe genotypes (Table 4.7).

Table 4. 6. Seeds yield of sesame genotypes:

Sesame genotypes	Yield (kg/ha)
Alradom	11.4 [a]
Abraway	16.2 [ab]
Bash	12.3 [abc]
Huria15	16.6 [abc]
Alsodona	12.3 [abc]
Carawy	19.4 [bc]
Kenana	21.7 [c]
Soliamani	12.8 [c]
Tailandi	14.6 [c]
Varity17	16.8 [c]
SE±	**2.9**
LSD	**6.1**
CV%	**23.4**

Means within a column followed by the same letter (s) are significantly different according to LSD-Test at 5%.

Table 4.7. Dry weight of sesame genotypes

Sesame genotypes	Dry weight(g)/plant
Alradom	0.19 [a]
Abraway	0.18 [a]
Bash	0.12 [a]
Huria15	0.26 [a]
Alsodona	0.28 [ab]
Carawy	0.24 [ab]
Kenana	0.28 [ab]
Soliamani	0.20 [ab]
Tailandi	0.19 [ab]
Varity17	0.23 [b]
SE±	**0.05**
LSD	**0.11**
CV%	**20.51**

Means within a column followed by the same letter (s) are significantly different according to LSD-Test at 5%

4-3. Correlation between sesame seed yield and others parameters

Number of branches displayed significantly positive low correlation with plant height (r= 0.364*). However, number of capsules showed highly correlation with plant height (r=0.514**) and number of branches (r= 0.502**) (Table 4.8). Sesame dry weight showed low correlation with height (r= 0.445*) and number of capsules (r= 0.435*). Number of seeds per capsules significantly exhibited negative correlation with plant height, number of branches, number of capsules and sesame dry weight (Table 4.8). Thousands seed weight displayed a negative correlation with plant height, number of capsules and number of seeds (r= -0.026, -0.071 and -0.306, respectively). Sesame seeds yield displayed low positive correlation with number of capsules (r= 0.388*) and dry weight (r=0.452*). However, showed a negative correlation with number of branches (r= -0.034) (Table 4.8).

4-4. Path coefficient analysis:

The highest direct effect (0.482149) on grain yield was exerted by number of capsules followed by dry weight (0.399691). Similar result was exhibited on number of branches. The lowest positive direct effect (0.128991) was exerted to seed weight (Table 4.9). Highest negative direct effect was exhibited for plant height (-0.17789). The lowest negative direct effect was exerted by number of branches (-0.30083). The highest positive indirect effect on grain yield was exhibited by number of capsules (0.247825) followed by dry weight (0.177863). The lowest positive indirect effect on grain yield was exerted for plant height (0.004625) followed by dry weight (0.009992) (Table 4.9). The highest negative indirect effect was exhibited by number of branches (-0.15102) followed by plant height (-0.09143). Whereas, the lowest negative indirect effect was exhibited by seed weight (-0.00335) followed by number of branches (-0.00421) (Table 4.9).

Table 4.8. Correlation of sesame seed yield with other traits.

	PH	NB	NC	DW	NS	SW	SY
PH	1	0.364*	0.514**	0.445*	-0.091	-0.026	0.123
NB		1	0.502**	0.253	-0.102	0.014	-0.034
NC			1	0.435*	-0.125	-0.071	0.388*
DW				1	-0.041	0.025	0.452*
NS					1	-0.306	0.062
SW						1	0.065
SY							1

PH= Plant Height, NB= Number of branch, NC= Number of Capsules, DW= Dry Weight, NS= Number of Seeds, SW= 1000 Seed Weight and SY= Seed Yield.

Table 4.9. Path coefficient analysis of ten sesame genotypes traits evaluated under Field condition at Shambat.

	PH	NB	NC	DW	NS	SW
PH	**-0.17789**	-0.1095	0.247825	0.177863	-0.01194	-0.00335
NB	-0.06475	**-0.30083**	0.242039	0.101122	-0.01339	0.001806
NC	-0.09143	-0.15102	**0.482149**	0.173866	-0.01641	-0.00916
DW	-0.07916	-0.07611	0.209735	**0.399691**	-0.00538	0.003225
NS	0.016188	0.030684	-0.06027	-0.01639	**0.131255**	-0.03947
SW	0.004625	-0.00421	-0.03423	0.009992	-0.04016	**0.128991**

Direct effects= the diagonal
Indirect effect= off diagonal

PH= Plant Height, NB= Number of branch, NC= Number of Capsules, DW= Dry Weight, NS= Number of Seeds, SW= 1000 Seed Weight and SY= Seed Yield.

CHAPTER FIVE

Discussion

The results were showed highly significant differences (P<0.01) in plant height between the sesame genotypes. Therefore Alsodona sustained the tallest plant height, while Tailandi displayed the lowest. However, there was no significant difference between genotypes Alradom, Bash and Tailandi, a significant variation in plant height among different sesame genotypes has been reported by (Abdalla, 2003; Ngala *et al*., 2013 and Negasa, 2014). The results reported by El Naim *et al*. (2012) obtained for sesame, also agreed with this result where they reported that plant height varied among different sesame genotypes. In contrast to this result, Naser *et al*. (2012) reported statistically non-significant differences on plant height of sesame due to effects of variety. The highest number of branches was recorded for genotypes Alradom, followed by genotypes Abraway, Alsodona, Soliamani and Kenana. The variations in number of branches per plant were detected in sesame genotypes in previous studies (El Naim *et al*., 2010). Geremew *et al*. (2012) reported that number of branching is affected by seed rate, rainfall, day length and variety.

The statistical analysis for yield attributes showed that no significant differences between genotypes in capsule number per plant, seeds number per plant, 1000 seed weight, and dry weight. Among the ten genotypes tested, A Abraway cultivar displayed the highest number of capsules, while Bash and Tailandi displayed the lowest**,** as compared to other genotypes. The possibility for variation among genotypes regarding that capsule number have been attributed to the adaptation to the length of day and directly related to the flower number per plant, which can be seriously affected by the climatic conditions (Söğüt, 2008).The economic part of the plant is directly related to number of branches and the total number of capsules per plant.

The results of analysis of variance showed non- significant differences in number of seeds per capsule between sesame genotypes. Carawy produced the highest number of seeds capsule (64.6), while Alsodona produced the lowest number of seeds capsule (50.3), in comparison to the other sesame genotypes. Tailandi, Kenana and Abraway exhibited comparable number of seeds capsule (Table 4.4). El Mahdi *et al*. (2007) also found that the number of capsules per plant was significantly affected by sowing dates and sesame genotypes. Negasa (2014) reported that field observations by many researchers revealed a large amount of variations in days to flower initiation, plant growth, number of branches and yield components such as number of capsules, number of seeds per capsule, seed yield per plant between different sesame genotypes. The variation of seed number per capsule among genotypes could be due to the late-blooming stage; consequently, the lower seeds number per capsule occurs.

The weight of thousand seeds was not significantly ($P<0.05$) influenced by sesame genotypes. Varity 17 gave the highest significantly for 1000 seed weight (4.6 g), followed by Tailandi and Kenana (3.6-3.7 g), while variety Alsodona and Alradom displayed lowest seeds weight (3.2 g) (Table 4.5), similar result was obtained by (El Mahdi *et al*., 2007), in contrast, Negasa, (2014) found that the 1000 seeds weight of sesame was highly significantly ($P<0.01$) influenced by genotypes. El Naim *et al*. (2012) also reported that variety Hirhri had heavier seed weight (3.9 g) than genotypes Elobeidl (3.2 g) and Promo (3.1 g).

The results of analysis of variance showed a significant differences in sesame seed yield (ton/ha) between the genotypes. Among the ten sesame genotypes, Kenana gave the highest seed yield (21.1 t/ha), followed by variety Carawy (19.4 t/ha) while variety Alradom gave the lowest seed yield (11.4 t/ha), as compared to another genotypes (Table 4.6), similar result was obtained by (El Mahdi *et al*., 2007) who found that sesame seed yield was significantly affected by sowing dates and genotypes. In contrast, El Naim *et al.* (2010) who found that no significant effect on seed yield per plant and final seed yield (t/ha) between sesame cultivers. Although sesame has numerous genotypes and ecotypes adapted to various ecological conditions (Nzikou *et al*., 2009). Basu *et al*. (2009) reported that seed yield is known to be a complex trait governed by polygene and therefore is influenced more by environmental factors.

The results of analysis of variance showed significant differences in sesame seed yield (kg/ha) between the cultivars. Among the ten sesame genotypes, Kenana gave the highest seed yield (21.1 kg/ha), followed by genotype Carawy (19.4 kg/ha) while genotype Alradom gave the lowest seed yield (11.4 t/ha), as compared to another genotypes. Similar result was obtained by (El Mahdi *et al*., 2007) who found that sesame seed yield was significantly affected by sowing dates and genotypes. Although sesame has numerous genotypes and ecotypes adapted to various ecological conditions (Nzikou *et al*., 2009). Basu *et al*. (2009) reported that seed yield is known to be a complex trait governed by polygene and therefore is influenced more by environmental factors.

Analysis of variance showed that non-significant difference in sesame dry weight between the various genotypes. Alsodona, Hyria15, Carawy and Kenana genotypes gave the highest and comparable dry weight (0.24 - 0.28 g), while Bash displayed the lowest dry weight (0.12 g), in comparison to other genotypes (Table 4.7). Similar result was obtained by Abdullahi (2011), who found no significant differences in dry matter between two sesame genotypes.

Number of capsules and dry weight had highest correlation with yield, whereas the lowest positive correlation shows for plant height with yield. While the highest negative correlation was detected by number of branches with yield. Similar result was obtained by Salehi *et al*, (2010); Fazel Akbar *et al*, (2011). With an experiment concluded yield had a high positive correlation with traits such as, number of capsules per plant, dry weight. The highest direct effect (0.482149) on grain yield was exerted by number of capsules followed by dry weight (0.399691), similar result was exhibited on number of capsules his finding agreed with those of Ibrahim and Khidir (2012) and Azeez and Morakinyo (2011), who revealed that number of seeds per capsule among other yield attributes had the highest direct influence on seed yield per sesame plant.

Conclusion and Recommendations

Conclusion

1. Bash genotype exhibited shortest plant height, lowest number of branches and number of capsules.
2. Kenana and Carawy genotypes gave the highest seed yield, while Bash, Alsodona, Soliamani and Alradom genotypes displayed the lowest**.**
3. Kenana and Carawy suitable genotypes to cultivate under irrigation in Shambat area.
4. The highest positive correlation with the most important yield components indicated that number of capsules following number of branches, whereas the lowest positive correlation show for dry weight following number of capsules, while the highest negative correlation was detected by number of seeds following number of branch. The highest direct effect on grain yield was exerted by number of capsules followed dry weight.
5. genotypes Kenana, Carawy are promising due to their high potential in grain yield in combined such as number of capsules and yield

Recommendations

1. The experiment should be repeated for another year in two locations under irrigating and rain-fed system with additional treatments (nitrogen fertilizer) to confirm the results.

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APPENDICES

Appendix 1: The semi-desert climate

Sun-shine duration	3650 hour/year
Solar radiation	22.7 MJ/m^2/day
Maximum teature	42 C^o (MAY)
Minimum temperature	12 C^o(January)
Temperature range	30 C^o
Rainfall	100-250 mm/annum
Evaporation	2400 mm/annum

Appendix 2: Chemical and physical properties of the field soil

pH	8.2
ECC ds/m	0.5
SAR	4.6
Soluble cation (meq/1) Ca+Mg Na K	 0.9 3.1 0.3
CL meq/L	10.3
N%	0.04
P p.p.m	3.1
$CaCo_3$ %	2.00
Sand%	15
Silt %	23
Clay %	62

Appendix 3: Analysis of variance of plant height

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	F. Value	P
Replication	2	115.4	57.720		
Treatments	9	7626.1	847.347	6.38	0.000**
Error	18	2391.9	132.882		
Total	29	10133.4			

** High significant differences at 5 % probability level

Appendix 4: Analysis of variance of Number of branches

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	F. Value	P
Replication	2	5.8741	2.8741		
Treatments	9	125.712	13.9683	5.37	0.0012**
Error	18	46.800	2.6000		
Total	29	178.263			

High significant differences at 5 % probability level

Appendix 5: Analysis of variance of Number of capsules

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	F. Value	P
Replication	2	46.86	23.431		
Treatments	9	2335.92	259.546	0.82	0.6024^{Ns}
Error	18	5667.56	314.864		
Total	29	8050.33			

Ns: Not significant differences at 5 % probability level

Appendix 6: Analysis of variance of Number of seeds

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	F. Value	P
Replication	2	931.47	465.733		
Treatments	9	596.80	66.311	0.51	0.8458^{Ns}
Error	18	2323.47	129.067		
Total	29	3851.47			

Ns: Not Significant differences at 5 % probability level

Appendix 7: Analysis of variance of Dry weight

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	F. Value	P
Replication	2	0.02931	0.01465		
Treatments	9	0.07295	0.00811	1.69	0.1639^{Ns}
Error	18	0.08629	0.00479		
Total	29	0.18855			

Ns: Not significant differences at 5 % probability level

Appendix 8: Analysis of variance of 1000 seeds weight

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	F. Value	P
Replication	2	0.8375	0.41875		
Treatments	9	4.2380	0.47089	0.88	0.5610^{Ns}
Error	18	9.6475	0.53597		
Total	29	14.7230			

Ns: Not significant differences at 5 % probability level

Appendix 9: Analysis of variance of Yield

Source of variation	Degree of Freedom	Sum of Squares	Mean Square	F. Value	P
Replication	2	121.209	60.6043		
Treatments	9	282.331	31.3701	2.41	0.0533*
Error	18	233.871	12.9928		
Total	29	637.410			

* Significant differences at 5 % probability level