EFFECT OF SOWING DATE, SEED RATE AND NITROGEN FERTILIZATION ON YIELD AND OTHER TRAITS OF CUMIN (*Cuminum cyminum* L.) GROWN UNDER RAINFED CONDITIONS OF JORDAN

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This Dissertation (Effect of Sowing Date, Seed Rate and Nitrogen Fertilization on Yield and Other Traits of Cumin (*Cuminum cyminum* L.) Grown under Rainfed Conditions of Jordan) was successfully defended and approved on April 13, 2006

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DEDICATION

This work is dedicated to my mother, father, brothers, sisters, wife and sons.

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ABSTRACT

Cumin (*Cuminum cyminum* L.) is a small annual herb belongs to the *umbelliferae* family, native to the Mediterranian region. Cumin has different usages; as a flavouring agent in food, and has several important medicinal uses. Information on planting date, nitrogen fertilization and seeding rate of cumin is not available in this region. Therefore, a study was conducted to investigate the effect of planting dates, nitrogen fertilizer levels and seeding rates on the yield and some agronomic characteristics of cumin. The experiment was implemented during the growing season of 2004/2005 at two locations; Mushaqar and Maru experimental stations, which belong to National Centre for Agricultural Research and Technology Transfer (NCARTT).

The treatments comprised of three planting dates (early December, late December 2004 and mid to late January 2005), three nitrogen fertilizer levels (without nitrogen, 20 kg N ha^{-1} and 40 kg N ha^{-1}), and four seeding rates (15, 20, 25 and 30 kg ha^{-1}). The experiment was a split-split plot experiment using the randomized complete block design with three replications. Planting dates were the treatment applied to the main plots, nitrogen fertilizer levels in sub plots, and seeding rates in sub-sub plots.

The results at Maru revealed that early sowing on December 1 resulted in an increase in grain yield by 26% and 64%, and an increase in biological yield by 31% and

68% as compared to sowing on December 29 and January 31, respectively. Also early sowing resulted in an increase in plant height, number of branches per plant, number of umbels per plant, number of seeds per umbrella, number of seeds per plant, but a decrease in weight of 1000 seed. Early sowing was accompanied with an increase in plant growth cycle. Growth cycle of plants sown early in the 1st planting date lasted for 158 days as compared to 134 and 111 days for 2nd and 3rd planting dates, respectively. Also plants sown in the 1st planting date were accumulated 1155 heat units as compared to 1025 and 988 heat units for those in 2nd and 3rd planting dates, respectively. At Mushaqar, plants sown early on December 2 were completely killed by the around zero temperature occurred on the night of March 26. Plants sown on December 30 were taller but having lower number of branches as compared to those sown later on January 17. Gowth cycle of plants sown on December 30 was lasted for 143 days as compared to 132 days for plants sown on January 17. But the accumulated heat units for plants sown on December 30 were 950 as compared to 1032 heat units for those sown on January 17.

Plants received 20 kg and 40 kg N ha^{-1} at Maru gave a higher grain yield by 22% and 27%, and a higher biological yield by 17% and 28% as compared to unfertilized plants. Moreover, nitrogen fertilization increased plant height, number of branches per plant and number of umbels per plant, but it did not affect harvest index and oil content. While at Mushaqar, nitrogen fertilization increased number of branches per plant and plant height only.

At Maru, 30 kg ha^{-1} seeding rate gave the highest grain yield and biological yield, however, plants sown at a seeding rate of 15 kg ha^{-1} gave the highest number of branches per plant, number of umbels per plant and number of seeds per plant, whereas the highest 1000 seed weight was recorded under the rate of 20 kg ha^{-1}. At Mushaqar, only plant height and number of branches per plant were significantly affected by seeding rate. The tallest plants were recorded at the rate of 25 kg ha^{-1}, while the rate of 15 kg ha^{-1} gave the highest number of branches per plant.

1. Introduction

Cumin (*Cuminum cyminum* L.) is a small annual herb, which belongs to the *umbelliferae* family, native to the Mediterranean region. Cumin is primary cultivated in Europe, Asia, Middle East, and North Africa. India and Iran are the largest cumin exporters, whereas Turkey, Iran, and Syria are the main producers in the region (Al-Wareh *et al*.1993; Grieve, 2005; Non-wood forest, 2005). In the Middle East, cumin is grown as a winter crop. It can be successfully grown within a temperature range between 9 to 26 ºC, and an average annual rainfall greater than 300 mm, in a sandy loam soils with pH range between 4.5 to 8.3 (Cumin, 2005).

Cumin essential oil consists of many volatile constituents that give it a strong aromatic smell such as cumin aldehide, B-pentene, P-cymene (Cumin, 2005; Grieve, 2005).

Cumin shows high antifungal activity against various pathogenic fungi, and high antibacterial activity (Li and Jiang, 2004)

The seed is widely used as a food flavoring agent in cheeses, pickles, sausages, soups, and bean dishes, and has several important medicinal uses; it is beneficial to the digestive system and acts as a stimulant to the sexual organs, used in coughs as painkiller and to treat rotten teeth. It is also used in the treatment of flatulence and bloating, reducing intestinal gas, and in treatment of insomnia, colds, fevers, and to improve milk production (Cumin, 2005). Cumin is also used in veterinary practices (Li and Jiang, 2004).

Cumin has been grown in Jordan in very limited areas by the National Centre for Agricultural Research and Technology Transfer (NCARTT) as demonstrations in farmers' fields and in NCARTT research stations (Mushaqar and Maru). The area planted to medicinal and herbal crops (including cumin) was 243 hectares during the

2001-2002 season (Haddad and Turk, 2002; Khairallah, 1998). Seed yield of cumin planted in Mushaqar station in1998 under rainfed conditions was 320 kg ha^{-1} using seed drill and mechanical harvesting (Khairallah, 1998).

There is a good opportunity to expand in herbal plants cultivation (including cumin) in Jordan because of it's adaptation to the rainfed production system and its high economic return, which is higher than that obtained from other rainfed crops currently under cultivation such as wheat, lentil and chickpea which illustrated in Table 1 (Khairallah, 1998).

Table 1: Actual production cost and import price of some medicinal plants as compared to traditional crops grown under rainfed conditions of Jordan.

	Wheat	Lentil	Fenugreek	Anise	Cumin
Actual production cost (JD ton^{-1})	128	360	285	429	350
Import price (JD ton^{-1})	105	350	465	1070	700

This show the high return that could be obtained from planting the medicinal plants as compared to growing the traditional crops (Khairallah, 1998).

Justification:

As indicated earlier, there is a need to introduce new crops to Jordan agriculture, and to find out their proper management practice. Therefore, the justifications for undertaking this work are the followings:

1. Jordan import cumin from Syria, India and Sudan. The imported quantities were 275 tones during 2003, with a value of 170,000 JD, and 490 tones during 2002, with a value of 330,000 JD (Department of Statistics, 2003).

2. Jordan has limited agricultural resources especially lands which is mainly rainfed. The main crops under cultivation in these areas are cereals and food legumes, which give low return to farmers. Moreover, field size is very small. Therefore, there is a need to introduce alternative high value crops under certain cropping system that produces higher return per unit of land. Medicinal and herbal plants are one viable alternative; they are high value crops, can be adapted to small fields, and give high economic returns to farmers.

3. Jordanian farmers have limited experience in medicinal and herbal plants cultivation, and no written documents are available on this subject. Therefore, there is a need for research to find out the proper cultivation methods and practices for medicinal plants including cumin under the rainfed conditions of Jordan, to reach the proper recommendations that could be used by farmers.

Very few published work is available on cumin cultivation world wide, and no information available on the cultivation practices of cumin under Jordan environmental conditions. Therefore, this research was conducted to find out the proper planting date, nitrogen fertilization levels, seeding rates and the best combination between them that will give the highest cumin productivity under wheat-based rainfed production system of Jordan.

2. Literature Review

Information on cumin cultivation is very limited in the literature, therefore, this review will try to cover all the information available on cumin and will cover crops from the family of cumin and other crops that have similar growth habit and input requirements.

2.1 Sowing date

Luayza *et al.* (1996), working on coriander (*Coriandrum sativum)* under irrigated conditions of Argentina, reported that late sowing caused a reduction in total growth cycle of the plant, from 170 days for the first sowing date (1 to15 July) to 100 days for the last sowing date (16 to 30 September). They also reported that delay sowing reduced plant height from 68 cm to 53 cm, seed yield from 1731 to 805 kg ha^{-1}, number of umbels per plant from 12.5 to 8.8, and weight of 1000 seeds from 12.1 to 11.8 g. Similar results were reported by Agra *et al.* (1999), where they found that early sowing of coriander grown in Western Canada in 1994 to 1996 resulted in higher seed yield, seed weight, and essential oil yield. Gil *et al.* (1999), in a trial on coriander near Buenos Aires, Argentina, reported that maximum total biomass was higher for sowing on June than for sowing on July. A study was conducted at CSIDC (Canada Saskatchewan Irrigation Diversification Centre) during 1990 to 1996 to evaluate the effect of sowing dates on coriander yield found that delay sowing from May 4 to May 25 reduced seed yield from 2510 to 1530 kg ha^{-1}, and essential oil yield from 62 Litter ha^{-1} to 55 L ha^{-1} (CSIDC, 1996).

D'Antuono *et al.* (2002), in Northern Italy, found that grain yield of black cumin (*Nigella sativa* L.) decreased from 1337 to 486 kg ha^{-1} with delaying sowing from March to May due to the reduction in both seed number per plant and mean seed weight.

Yield of fennel (*Foeniculum vulgare* Mill. Var. azoricum Thill.) under the conditions of south Italy decreased from 1600 kg ha^{-1} to 900 kg ha^{-1} as a result of delaying sowing from August to September. In addition, blooming of primary umbel of crop sown on September 1 occurred 14 days later as compared to crop established on August 1 (Bianco *et al.*, 1994).

Javanshir *et al.* (2000), reported that essential oil yield of anise (*pimpinella snisum* L.) decreased from 18 kg ha^{-1} when planted on April 1 to 8 kg ha^{-1} when planting was delayed until April 29.

According to Randhawa *et al.* (1987), Dill (*Anethum graveolens* L.) yield under Punjab conditions was highest when sown on October 15 as compared with later sowing dates. A study was conducted by Hakan (2003) under Anatolia conditions, Turkey, reported that delaying sowing of rapeseed (*Brassica napus* L.) from April to May resulted in reduction in seed yield from 1166 kg ha^{-1} to 917 kg ha^{-1}. Similar results were reported by Yousaf *et al.* (2002) in a trial conducted on the same crop at the Arid Zone Research Institute, Bahawalpur, Pakistan.

2.2 Nitrogen fertilization

Safwat and Badran (2002), working under irrigated conditions of Egypt, found that cumin (*Cuminum cyminum* L.) yield and yield components increased due to the use of different organic sources of nitrogen (compost, poultry manure and farmyard manure) as well as chemical fertilizers, with the highest values being obtained from the higher rates of nitrogen (200 kg N ha^{-1}).

Buntain and Chung (2005) reported that there was no significant effect of nitrogen fertilization on yield components of fennel (*Foeniculum vulgare).* Similarly, Damato *et al.* (1994) working with fennel found that nitrogen rate did not affect the yield components of fennel in the second year of the experiment, while in the first year, 1000 seed weight was higher with 150 kg N ha^{-1} and 300 kg ha^{-1} as compared with the control treatment (without nitrogen).

Lenardis *et al.* (2000), reported that the response to nitrogen was related to genotype characteristics of coriander, where relatively high levels of nitrogen fertilizer should be used in the production of Argentinean land-race coriander, and relatively moderate levels of nitrogen should be used in the production of European land-race.

Garrabrants and Craker (1987), working on Dill *(Anethum graveolens* L.) reported that the addition of 120 kg N ha^{-1} resulted in doubling the production of fresh weight per plant as compared with no added nitrogen. Similar results were recorded by Randhawa *et al.* (1996), where they found that each increase in nitrogen level up to 90 kg ha^{-1} increased the seed yield of Dill, however, further increase in N did not affect the seed yield significantly. In an experiment conducted by Randhawa *et al.* (1984) on Dill at Punjab, they found that in order to get higher seed yield, the crop should be sown in mid October (rather than 30 September, 30 October, 15 November, 30 November and 25 December) in lines 30 cm apart (rather than 5,10,15,45, 60 and 75 cm) and using 10 kg seeds ha^{-1}, and should be supplied with 90 kg N ha^{-1}.

Nikolova *et al.* (1999), working on Chamomile (*Chamomilla recutita* L.) in Bulgaria, reported that nitrogen and potassium increased the yield, while phosphorous increased the oil content, and the highest yields of inflorescence and oil were achieved when the ratio between the major nutrients N:P:K was 1:1:1 (in 120 kg ha^{-1} active ingredients). On the other hand, an experiment on chamomile was conducted by Junior and Castellane (1999) in Brazil, indicated that there was no significant effect of nitrogen application rates or source on flowers yield or on the essential oil content.

The response of rapeseed (*Brassica napus* L.) to nitrogen fertilization was studied under the conditions of Erzurum, Turkey. The results showed that nitrogen rate of 160 kg ha^{-1} gave the highest seed yield as compared with 0, 80 and 240 kg ha^{-1}(Hakan, 2003).

2.2 Seeding rate

Damato *et al.* (1994), in a study which was conducted for two years at Massafara and Rutigilano in south Italy, found that the number of umbels per fennel plant decreased linearly from 93 to 47, and yield per plant decreased linearly from 133 to 57 gram as the plant density increased from 1.7 to 5 plants m^{-2}. But grain yield per unit area increased from 2000 kg ha^{-1} to 2500 kg ha^{-1} as the plant density increased from 1.7 to 5 plant m^{-2}. In an other experiment by Bianco *et al.* (1994) who worked on fennel at Rutigliano (south Italy), they found that as plant density decreased from 5 to 1.7 plant m^{-2}, plant height at the flowering of primary umbrella decreased from 132 cm to 115 cm, stems per plant increased from 1.8 to 2.7, umbels per plant increased from 50 to 84, seeds per plant increased from 40 to 68, and grain yield per unit area decreased from 1674 kg to 1025 kg ha^{-1}.

On the other hand, Garrabrants and Craker (1987) reported that the highest yield of Dill (*Anethum graveolens* L.) was obtained at the narrowest row width (15 cm) and closest plant spacing within the row (10 cm). The same results were obtained from an experiment conducted also on Dill at Punjab University, India, where seed yield decreased with increasing row spacing. The closer row spacing (30 and 45 cm) produced significantly more seed yield (1014 and 919 kg ha^{-1} respectively) as compared with wider row spacing of 60 cm, which gave 745 kg ha^{-1}. It was also found that a spacing of 10 cm between plants out yielded the closer or wider spacing (Randhawa *et al.*, 1996). Randhawa *et al.* (1987) found that seed rate and row spacing did not affect oil content of Dill in a trial conducted at Punjab Agricultural University, India.

Gil *et al*. (1999), working on coriander (*Coriandrum sativum)* found that the plant density to obtain maximum biomass and grain yield was higher in a wet year than in a dry year. Kizil and Ipek (2004) reported that the optimum row spacing of coriander to obtain the highest yield under the conditions of Diyarbakir, Turkey, was 30 cm, compared with 20, 40, 50 and 60 cm.

Mert *et al.* (2002), reported that Artemisia (*Artemisia annua* L.) produced the highest essential oil content and the highest oil yield when planted at a plant density of 15 plants m^{-2} as compared with 5, 10, 20, 25 and 30 plants m^{-2}. Tuncturk *et al.* (2005) reported that, under the conditions of Van, Turkey, the optimum seeding rate of black cumin (*Nigella sativa)* was 15 kg ha^{-1} as compared with 5, 10, and 20 kg ha^{-1}.

3. Materials and Methods

3.1 Location: This study was conducted under rainfed conditions during the growing season of 2004/2005 at two agricultural research stations; Mushaqar and Maru. Both stations belong to NCARTT. Basic information on the two stations is presented in Table 2, Figure 1 and Appendix B.

Table 2: Information on the two stations where the research was conducted.

	Mushaqar	Maru
Location	28 km south-west Amman	100 km north Amman
Longitude	35° 46` 30 East	35° 53` 00 East
Latitude	31° 47` 35 North	32° 36` 25 North
Elevation	790 m	520 m
Soil type	Brown-reddish brown, clay loam.	Red, clay soil, deep, non-stony, nearly level.
Annual average rainfall (10 years), from 1994-2003	316 mm	400 mm

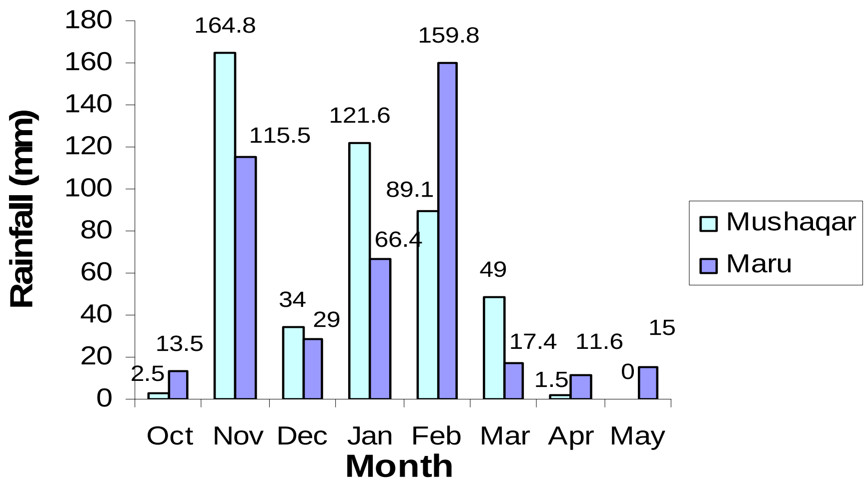

Figure 1: Monthly rainfall (mm) during the growing season of 2004/2005.

The two locations represent the potential environment where cumin could be grown in Jordan because they fall within the wheat–based production system, receiving more than 300 mm annual rainfall.

3.2 Experimental design and treatments

The experiment was laid out in split-split plot with randomized complete block design, with three replications (Fig. 2), where the three planting dates occupied the main plots, three fertilization treatments occupied the sub-plot, and the four seed rates the sub-sub plots. Sowing was performed in the following dates:

Date	Mushaqar	Maru
1	December 2, 2004	December 1, 2004
2	December 30, 2004	December 29, 2004
3	January 17, 2005	January 31, 2005

The nitrogen fertilization levels were without nitrogen application (control), 20 kg nitrogen ha^{-1}, and 40 kg nitrogen ha^{-1}. Nitrogen was applied at planting in the form of urea (46%N). The four seeding rates were 15, 20, 25, and 30 kg ha^{-1}, which are equivalent to 526, 688, 860, and 1032 plants m^{-2}, respectively.

The area of each sub-sub plot was 4.4 m^{2} consisting of 6 rows, 4 meters long and 18 cm apart. The cumin seeds were received from NCARTT Maru station. It is a Syrian local variety, which is grown by farmers in Jordan in the last few years.

3.3: Crop management

The seed bed was prepared using duck foot plough. Rows were opened and planted manually at a sowing depth of about 2 to 3 cm. Nitrogen fertilizer in the form of urea (46% N) was broadcasted on each sub plot at planting. Narrow leaf weeds were controlled at the beginning of the season by using the herbicide “fusillade”, and the broad leaf weeds were controlled manually as needed.

Figure 2: Field lay out of the experiment (one replication)

Date 2**(main plot)**	Date 1	Date 3
S2 (sub-sub plot)	S3	S3
S1 **N20** (sub plot)	S4 **N40**	S1 **N0**
S3	S2	S2
S4	S1	S4
S1	S3	S3
S4 **N0**	S2 **N0**	S1 **N40**
S3	S1	S4
S2	S4	S2
S1	S3	S3
S3 **N40**	S4 **N20**	S4 **N20**
S4	S2	S1
S2	S1	S2

(Date: planting date, S: seeding rate, N: nitrogen fertilizer level)

3.4: Characters measured

<u>On plot basis:</u>

Days to emergence: Number of days from planting to 50% emergence.

Days to flowering: Number of days from emergence to 50% flowering.

Days to maturity: Number of days from emergence until 90% of umbels changes its color to yellow.

Heat units (Growing degree-days) to emergence, to flowering and to maturity: The specific heat requirement for a plant to grow and develop is the accumulated heat when the temperature for a 24-hour period is one degree above the minimum threshold (base temperature). The heat units were measured according to the following equation:

Heat units = $\{(T_{max}.\ °C + T_{min}.\ °C)/2\} - T_{base}$.

T_{max} = Maximum daily temperature

T_{min} = Minimum daily temperature

T_{base} = Minimum threshold temperature

Since the base temperature for cumin is not reported in the literature, we used the base temperature for barley, which is 5°C (Sinebo, 2002).

Plant height: The height of the plant (cm) from soil surface to the top of the plant, measured at maturity for five random plants sampled from each sub-subplot.

Biological yield and grain yield: At harvesting stage, the two outer rows and a half meter at both sides of each sub-subplot were lifted as borders, and the middle four rows were harvested by hand. The net harvested area of each sub-subplot was 2.2 meter square. Biological yield was obtained by weighing the above ground total dry matter including seeds of the harvested area. Grain yield was obtained after threshing the harvested plants.

Weight of 1000 seed: Obtained by weighing 1000 seeds.

Harvest index: Calculated as the ratio of grain yield to biological yield multiplied by 100.

Oil content: Oil content of 5 g seeds from each sub-subplot in two replicates at Maru location were extracted by using organic solvents (petroleum ether and diethyl ether). (Pomeranz, and Meloan, 2000). And essential oil content of 20 g seeds from representative sub-sub plots was extracted by means of steam distillation for two hours. (Li and Jiang, 2004).

Oil yield (kg ha^{-1}): calculated by multiplying oil% by grain yield.

On plant basis:

At maturity, ten plants were selected randomly from the inner rows of every sub-sub plot to measure the following characteristics:

Branch number per plant: number of main branches originating from first and second nodes.

Number of umbels per plant.

Number of seeds per umbrella.

Number of seeds per plant.

3.5: Statistical analysis:

Data from each location was analyzed separately using Gen Stat program (Eighth Edition), and a combined analysis of variance over locations was performed using MSTATC program (Michigan State University). Treatments means were compared using Least Significant Difference (LSD) at 5 % probability according to Steel and Torrie (1980). The correlation coefficient between the studied characters was calculated using Gen Stat program. The relationship and regression equation of treatment effect on some characters were conducted using Excel program for treatments with a significant F values only.

4. Results:

The results of the effect of planting dates, nitrogen fertilizer levels and seeding rates on yield and yield components and other traits of cumin in the two locations are presented in Table 3 through Table 38.

At Mushaqar location, the first planting date on December 2 was damaged by the frost, which occurred on the night of March 26, and as a result, no data was recorded on the first date. The plants in the second and third planting dates were also affected by the low temperature but they survived until they set seeds and gave yield. Nevertheless, the plants in the second planting date were more affected than those in the third planting date. It is also worth mentioning here, that the difference between the day and night temperature during this day was 20°C (22°C day temperature and 2°C night temperature).

Analysis of Variance tables and the significant of the studied treatments for the investigated characters are presented in appendix A.

4.1 Grain yield, biological yield and harvest index

4.1.1 Grain yield:

Main effects of planting dates, nitrogen fertilizer levels, and seeding rates on grain yield, biological yield, and harvest index are presented in Table 3 for Maru and Table 4 for Mushaqar. At Maru location, grain yield was significantly affected by planting date, nitrogen fertilizer levels, and their interaction, but was not affected by seeding rate and other interactions (Appendix A-1). While at Mushaqar, grain yield was not affected by any of the three treatments or their interactions (Appendix A-11).

At Maru, sowing early on December 1 resulted in 26% and 64% higher grain yield as compared to sowing on December 29 and January 31, respectively. In the contrary to that, sowing on December 30 at Mushaqar resulted in 3.5% lower grain yield as compared to sowing later on January 17. The relationship between planting date and grain yield at Maru was linear and highly significant and negative (Fig. 3).

Nitrogen fertilization increased grain yield at both locations, however, the increase at Mushaqar was not significant. The highest grain yield was obtained with 40 kg N ha^{-1} and the lowest was with no fertilizer application. At Maru, the increase in grain yield was about 22% for plants received 20 kg N ha^{-1} and 27% for plants received 40 kg N ha^{-1} as compared with unfertilized plants. While the increase at Mushaqar was about 5% and 8% for the two rates, respectively. The relationship between nitrogen fertilizer levels and grain yield at Maru was curvilinear and highly significant (Fig. 4).

As for seeding rates, the highest grain yield at Maru was obtained with a seeding rate of 30 kg ha^{-1}, which exceeded the yield under the seeding rate of 15 kg ha^{-1} by 18%. While at Mushaqar, the highest grain yield was obtained with a seeding rate of 25 kg ha^{-1}, which was about 20% higher than the yield obtained with a seeding rate of 15 kg ha^{-1}.

At Maru, only the interaction effect of planting dates and N fertilizer levels on grain yield was significant and presented in Table 5. The highest grain yield was obtained when the crop was planted on the first planting date with 40 kg N ha^{-1} while the lowest was when the crop was planted on the 3rd planting date with 40 kg N ha^{-1}. The best N fertilizer level for plants sown on the 1st and 2nd planting dates was 40 kg ha^{-1}, but for plants sown on the 3rd planting date was 20 kg ha^{-1}.

When the results were considered over the two locations, there was no significant difference in grain yield between the two locations (Table 6), however grain yield at Maru was higher than that at Mushaqar by about 14%. In addition, there were no significant effects of planting date, N fertilization, seeding rate or any of their interactions on grain yield (Appendix A-20).

4.1.2 Biological yield:

At Maru, and similar to grain yield, biological yield was significantly affected by planting dates, nitrogen fertilizer levels, seeding rates and the interaction between planting dates and nitrogen fertilizer levels (Appendix A-2). While at Mushaqar, biological yield was not affected by any of the three treatments or their interactions (Appendix A-12). At Maru, sowing early on December 1 resulted in 31% and 68% higher biological yield as compared to sowing on December 29 and January 31, respectively. While At Mushaqar, sowing on December 30 resulted in 6% lower biological yield as compared to sowing on January 17. The relationship between planting date and biological yield at Maru was significant curvilinear relationship (Fig. 5).

Nitrogen fertilization increased biological yield at both locations, the increase was significant at Maru but not at Mushaqar. The highest biological yield at Maru was recorded with 40 kg N ha^{-1} followed by 20 kg N ha^{-1}, and resulted in an increase in biological yield of 128% and 117% as compared to the yield obtained with no nitrogen fertilization for the two levels, respectively (Table 3). While at Mushaqar, the highest yield was obtained with 20 kg N ha^{-1} followed by 40 kg N ha^{-1}, with an increase of 109% and 107% of the yield with no nitrogen fertilization for the two levels, respectively (Table 4).

The relationship between nitrogen fertilizer levels and biological yield at Maru was curvilinear and highly significant (Fig. 6).

Increasing seeding rate increased biological yield significantly at Maru; biological yield of the crop sown at a seeding rate of 20, 25 and 30 kg ha^{-1} was about 113%, 115% and 123% of that sown at a rate of 15 kg ha^{-1}. While at Mushaqar, the highest biological yield was for crop sown at a rate of 25 kg ha^{-1}, followed by 20 kg ha^{-1} which gave

120% and 110% of the lowest biological yield obtained under a rate of 15 kg ha^{-1}, respectively (Table 4). The relationship between seeding rate and biological yield at Maru was curvilinear and significant (Fig. 7).

At Maru, only the interaction effect of planting date and nitrogen fertilizer level on biological yield was significant and presented in Table 7. The highest biological yield was obtained when sowing on December 1 with 40 kg N ha^{-1}, and the lowest biological yield was obtained when sowing on January 31 with 40 kg N ha^{-1}. For plants sown on December 1 and December 29, the highest biological yield was with 40 kg N ha^{-1}, while for plants sown on January 31 it was with 20 kg N ha^{-1}.

Over the two locations, there was no significant difference in biological yield between the two locations, however, biological yield at Maru was about 107% of that at Mushaqar (Table 6), also there was no significant effect of planting date, nitrogen fertilization, seeding rate or their interactions on biological yield.

Table 3: Main effects of planting dates, N fertilizer levels, and seeding rates on grain yield, biological yield (kg ha^{-1}) and harvest index of cumin grown at Maru during the growing season of 2004/2005.

Planting date	grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Dec. 1, 2004	1021	2199	46.4
Dec. 29, 2004	809	1674	48.3
Jan. 31, 2005	621	1309	47.4
LSD 0.05	195	386	5.3
Nitrogen level (kg N ha^{-1})			
0	702	1501	46.8
20	859	1753	49.0
40	890	1929	46.1
LSD 0.05	125	244	3.6
Seeding rate (kg ha^{-1})			
15	754	1530	49.3
20	815	1734	47.0
25	810	1762	46.0
30	889	1884	47.2
LSD 0.05	116	222	3.3

Table 4: Main effects of planting dates, N fertilizer levels, and seeding rates on grain yield, biological yield (kg ha^{-1}) and harvest index of cumin grown at Mushaqar during the growing season of 2004/2005.

Planting date	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Dec. 30, 2004	614	1352	45.4
Jan. 17, 2005	636	1438	44.2
LSD 0.05	471	829	6.5
Nitrogen level (kg N ha^{-1})			
0	599	1320	45.4
20	629	1444	43.6
40	648	1420	45.6
LSD 0.05	319	696	4.5
Seeding rate (kg ha^{-1})			
15	572	1266	45.2
20	625	1400	44.6
25	688	1516	45.4
30	616	1396	44.1
LSD 0.05	138	262	5.0

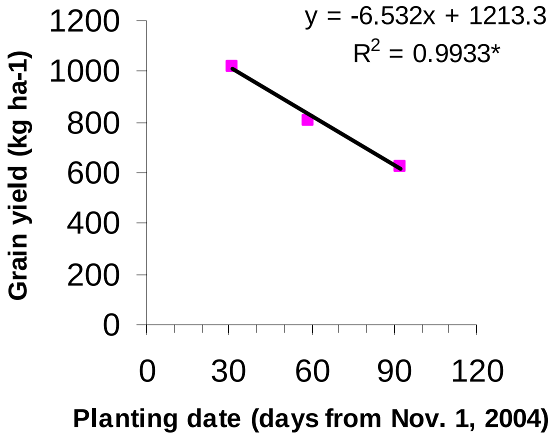

Figure 3: Relationship between planting dates and grain yield of cumin (kg ha^{-1}) grown at Maru. * = significant at 5%.

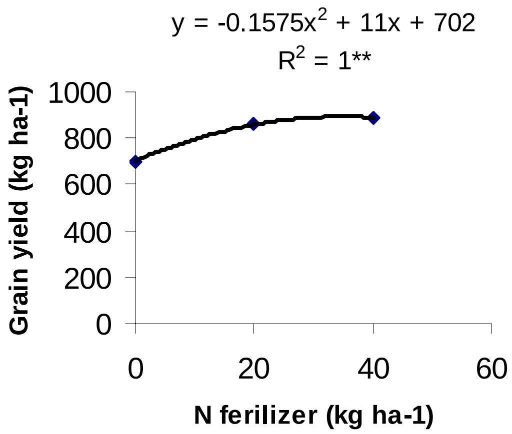

Figure 4: Relationship between nitrogen fertilizer levels and grain yield of cumin (kg ha^{-1}) grown at Maru. ** = significant at 1%.

Table 5: Interaction effects of planting dates and N fertilizer levels on grain yield (kg ha^{-1}) of cumin grown at Maru location during the growing season of 2004/2005.

Planting date	Nitrogen level (kg N ha^{-1})		
	0	20	40
Dec. 1, 2004	936	972	1155
Dec. 29, 2004	595	860	972
Jan. 31, 2005	576	746	542

LSD at 5% = 230 kg.

Table 6: Main effects of locations on different plant characters.

	Maru	Mushaqar*	LSD at 5%
Grain yield (kg ha^{-1})	715	625	186
Biological yield (kg ha^{-1})	1492	1395	370
Harvest index (%)	47.8	44.8	2.6
Branch plant^{-1}	2.39	2.38	0.10
Umbels plant^{-1}	9.40	12.00	1.90
Seed umbrella^{-1}	23.30	11.30	2.38
Seed plant^{-1}	217.5	136.5	61.3
1000 seed weight(gm)	3.26	2.69	0.07
Plant height (cm)	16.71	16.82	0.37

* Only second and third planting date's values were used in the analysis.

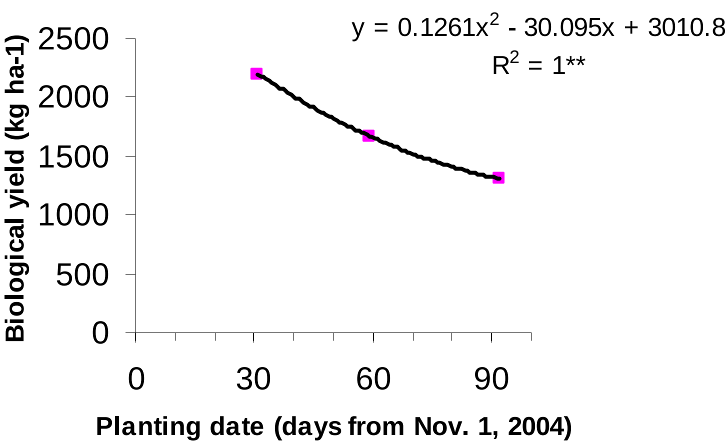

Figure 5: Relationship between planting dates and biological yield of cumin (kg ha^{-1}) grown at Maru. ** = significant at 1%.

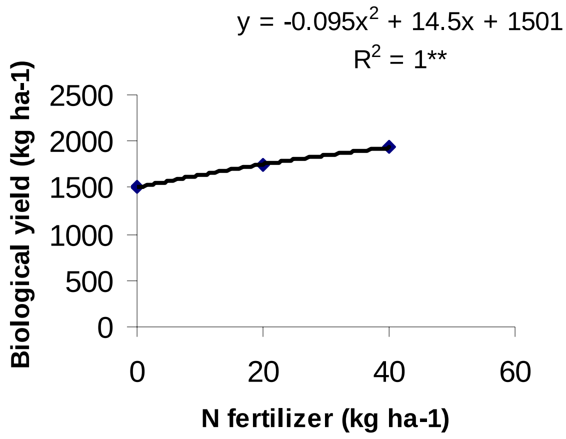

Figure 6: Relationship between nitrogen fertilizer levels and biological yield of cumin (kg ha^{-1}) grown at Maru. ** = significant at 1%.

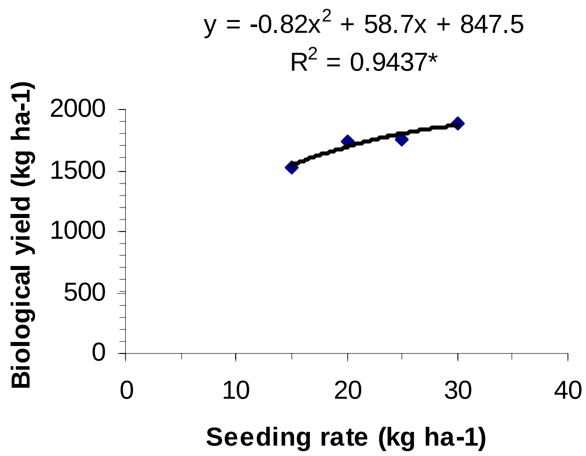

Figure 7: Relationship between seeding rates and biological yield of cumin (kg ha^{-1}) grown at Maru. * = significant at 5%.

Table 7: Interaction effects of planting dates and nitrogen fertilizer levels on biological yield (kg ha^{-1}) of cumin grown at Maru location during the growing season of 2004/2005.

Planting date	Nitrogen level (kg N ha^{-1})		
	0	20	40
Dec. 1, 2004	1957	2007	2633
Dec. 29, 2004	1299	1775	1949
Jan. 31, 2005	1246	1477	1205

LSD at 5% = 454 kg.

4.1.3 Harvest index:

Harvest index at both locations was not affected significantly by the three treatments or any of their interactions except the interaction between planting date, nitrogen fertilizer level and seeding rate at Maru location (Appendices A-3 and A-13). Harvest index values at Maru increased by delaying sowing with the highest value was for crop sown on December 29 and January 31 which was about 3% greater than the value on December 1 (Table 3). While at Mushaqar, harvest index was decreased by 3% in January 17 as compared to those sown on December 30 (Table 4).

The highest harvest index value at Maru was recorded with 20 kg nitrogen ha^{-1} and the lowest was with 40 kg nitrogen ha^{-1} (Table 3). While at Mushaqar, the highest harvest index value was with 40 kg nitrogen ha^{-1} and the lowest was with 20 kg nitrogen ha^{-1} (Table 4).

The highest harvest index value at Maru was obtained when the crop was sown at a seeding rate of 15 kg ha^{-1}, and the lowest value at the seeding rate of 25 kg ha^{-1} (Table 3). While at Mushaqar, the highest harvest index value was obtained when the crop was sown at a seeding rate of 25 kg ha^{-1} and the lowest was at the rate of 30 kg ha^{-1} (Table 4).

Interaction effects of planting dates, nitrogen fertilizer levels and seeding rates on harvest index at Maru are presented in Table 8. The highest value of harvest index was recorded when the crop was sown on January 31 at a seeding rate of 15 kg ha^{-1} and with 40 kg nitrogen ha^{-1}, and the lowest value was obtained when the crop was sown on January 31 at a seeding rate of 20 kg ha^{-1} and with 40 kg nitrogen ha^{-1}. For plants sown on December 1, December 29 and January 31, the highest values of harvest index were under a seeding rate of 15 kg ha^{-1}, but with no nitrogen fertilization, with 20 kg nitrogen ha^{-1}, and with 40 kg nitrogen ha^{-1} for the three planting dates, respectively.

There was a significant difference for harvest index between the two locations, with highest value at Maru that was higher than that at Mushaqar by about 7%.

Over locations, results indicated that harvest index values were significantly different between the two locations. However, there were no significant effect of planting date, nitrogen fertilizer level, seeding rate and their interactions on harvest index except the interaction effect of planting date, nitrogen fertilization and seeding rate, which is presented in Table 9. The crop at Maru gave the highest harvest index value with the combination of planting on January 31, with 15 kg seeds ha^{-1} and 40 kg nitrogen ha^{-1}, and the lowest harvest index value was for the crop grown at Mushaqar when sown on January 17, at a seeding rate of 20 kg ha^{-1} and without nitrogen fertilization.

Table 8: Interaction effects of planting dates, N fertilizer levels and seeding rates on harvest index of cumin grown at Maru location during the growing season of 2004/2005.

Planting date	N fertilizer level (kg N ha^{-1})	Seeding rate (kg ha^{-1})			
		15	20	25	30
Dec. 1, 2004	0	51.2	45.5	50.6	45.0
	20	50.6	49.2	46.4	48.0
	40	47.6	44.0	40.4	44.2
Dec. 29, 2004	0	45.2	45.7	47.2	44.4
	20	51.5	49.9	42.2	49.6
	40	46.1	51.7	49.6	50.8
Jan. 31, 2005	0	47.8	52.4	41.2	43.2
	20	50.8	51.7	50.5	52.1
	40	58.1	37.9	43.4	44.8

LSD at 5% = 10.4%.

Table 9: Over location interaction effects of planting dates, N fertilizer levels and seeding rates on harvest index of cumin grown at Maru and Mushaqar during the growing season of 2004/2005.

Location	Planting date	N fertilizer level (kg N ha^{-1})	Seeding rate (kg ha^{-1})			
			15	20	25	30
Maru	Dec. 29, 2004	0	45.2	45.7	47.2	44.4
		20	51.5	49.9	42.2	49.6
		40	46.1	51.7	49.6	50.8
	Jan. 31, 2005	0	47.8	52.4	41.2	43.2
		20	50.8	51.7	50.5	52.1
		40	58.1	37.9	43.4	44.8
Mushaqar	Dec. 30, 2004	0	46.3	52.6	44.4	42.7
		20	41.4	40.3	44.1	48.5
		40	47.4	48.1	37.7	40.6
	Jan. 17, 2005	0	45.4	35.4	49.3	47.8
		20	41.1	43.5	46.4	40.3
		40	47.3	45.0	46.1	47.1

LSD at 5% = 10.4%

4.2 Yield components

4.2.1 Number of branches per plant

Main effects of planting dates, nitrogen fertilizer levels and seeding rates on yield components are presented in Table 10 and Table 11 for Maru and Mushaqar, respectively.

At Maru location, number of branches per plant was significantly affected by planting dates, nitrogen fertilizer levels, seeding rates and their interactions (Appendix A-4). While at Mushaqar, the significant differences for number of branches per plant were for planting dates, nitrogen fertilizer levels and seeding rates but not their interactions (Appendix A-14).

Early sowing increased number of branches per plant at Maru and decreased it at Mushaqar. The highest number of branches at Maru was recorded for plants sown on December 1, which was 25% higher than the lowest value when plants were sown on December 29. While at Mushaqar, the highest number was recorded for plants sown on January 17, which was about 6% higher than the lowest value for plants sown on December 30. The relationship between planting dates and number of branches per plant at Maru was curvilinear and highly significant (Fig. 8).

On the other hand, nitrogen fertilization resulted in increasing the number of branches per plant at both locations. The highest number of branches was for plants received 40 kg nitrogen ha^{-1} and the lowest number was when no fertilizer was applied. The relationship between nitrogen fertilizer levels and number of branches per plant was curvilinear and highly significant at both locations (Fig. 9).

Increasing plant density decreased number of branches per plant at both locations. The highest number of branches was for plants sown at 15 kg seeds ha^{-1} and the lowest number was for plants sown at 30 kg seeds ha^{-1}. The relationship between seeding rates and number of branches per plant at Maru was curvilinear and highly significant (Fig. 10). While the relationship at Mushaqar was linear, negative and highly significant.

Interaction effects of planting dates and nitrogen fertilizer levels on number of branches per plant at Maru are presented in Table 12. The highest number of branches was recorded for plants sown on December 1 when received 40 kg nitrogen ha^{-1}, while the lowest number of branches was for plants sown on December 29 and received no N fertilizer. For plants sown on December 1 and on December 29, the highest number of branches obtained with 40 kg nitrogen ha^{-1}, while for plants sown on January 31 there was no significant effect of nitrogen fertilizer on number of branches per plant.

Interaction effects of planting dates and seeding rates on number of branches per plant at Maru are presented in Table 13. The highest number of branches was for plants sown on December 1 with 15 kg seeds ha^{-1}, and the lowest number was for plants sown on January 31 with 30 kg seeds ha^{-1}. All seeding rates used gave the highest number of branches when plants was sown on December 1, increasing seeding rate decreased number of branches per plant for all sowing dates used.

Interaction effects of nitrogen fertilizer levels and seeding rates on number of branches per plant at Maru are presented in Table 14. The highest number of branches was recorded for plants sown at a seeding rate of 15 kg seeds ha^{-1} and received 40 kg N ha^{-1}, and the lowest number was for plants sown at a rate of 30 kg seeds ha^{-1} and received no nitrogen fertilizer. For the seeding rates 15, 20 and 25 kg ha^{-1}, the highest number of branches were obtained with 40 kg nitrogen ha^{-1}, while the seeding rate of 30 kg ha^{-1} gave the highest number of branches with 20 kg N ha^{-1}.

Interaction effects of planting dates, nitrogen fertilizer levels and seeding rates on number of branches per plant at Maru are presented in Table 15. Plants sown on

December 29 with 15 kg seeds ha^{-1} and received 40 kg nitrogen ha^{-1} gave the highest number of branches per plant, while the lowest value was recorded for plants sown on December 29 with 25 kg seeds ha^{-1} and received 20 kg nitrogen ha^{-1}. Nevertheless, the highest number of branches per plant was recorded when plants sows on December 1 with any fertilizer and seed rates as compared with those sown on December 29 and January 31.

Over locations analysis showed no significant differences in number of branches per plant between the two locations (Table 6).

4.2.2 Number of umbels per plant:

At Maru location, there were significant effects of planting dates, nitrogen fertilization, seeding rates and their interactions on number of umbels per plant except for the interaction between nitrogen fertilizer levels and seeding rates (Appendix A-5). While at Mushaqar location, there were no significant effects for the three treatments and their interactions on number of umbels per plant (Appendix A-15).

At Maru, early sowing on December 1 resulted in 57% and 24% greater number of umbels per plant as compared to sowing on December 29 and January 31, respectively (Table 10). The relationship between planting dates and number of umbels per plant at Maru was curvilinear and highly significant (Fig. 11).

Increasing nitrogen fertilizer level increased number of umbels per plant at both locations; however, the increase at Mushaqar was not significant (Tables 10 and 11). The relationship between nitrogen fertilizer levels and number of umbels per plant at Maru was curvilinear and highly significant (Fig. 12).

Number of umbels per plant decreased as seeding rate increased at both locations (Tables 10 and 11). The relationship between seeding rates and number of umbels per plant was linear, negative and significant at Maru (Fig. 13).

Interaction effects of planting dates and nitrogen fertilizer levels on number of umbels per plant at Maru was significant and presented in Table 16, which indicate that the highest number of umbels was recorded with plants sown on December 1 without nitrogen fertilization, while the lowest value was found with plants sown on December 29 and without fertilization. For plants sown on December 1, the highest number of umbels per plant was with no nitrogen. However, sowing on December 29 and January 31 gave the highest number of umbels under 40 kg nitrogen ha^{-1} and 20 kg nitrogen ha^{-1}, respectively, while the lowest number of umbels was with 40 kg nitrogen ha^{-1} for the 1st planting date and with no nitrogen fertilizer for both 2nd and 3rd planting dates.

Interaction effects of planting dates and seeding rates on number of umbels per plant at Maru was significant (Table 17). The highest number of umbels was obtained when the crop was sown on December 1 under 15 kg seeds ha^{-1}, while the lowest number was obtained for plants sown on December 29 under 25 kg seeds ha^{-1}. Plants sown on December 1 and December 29 gave the highest number of umbels with a seeding rate of 15 kg ha^{-1}, while plants sown on January 31 gave the highest number of umbels with 25 kg ha^{-1} seeding rate.

Interaction effects of planting dates, nitrogen fertilizer levels and seeding rates on number of umbels per plant at Maru was significant (Table 18). The effects of planting date dominate the effects of the other treatments, where the combinations of the 1st planting date with all seeding rates and nitrogen fertilizer levels scored the highest numbers of umbels per plant as compared with those on 2nd and 3rd planting dates. Plants sown on December 1, without nitrogen fertilizer and with seeding rate of 15 kg seeds ha^{-1} gave the highest number of umbels per plant, whereas the lowest number of umbels was obtained for plants sown on December 29 under 25 kg seeds ha^{-1} and received 20 kg nitrogen ha^{-1}.

Analysis across the two locations indicates no significant differences in number of umbels per plant between the two locations; however, values at Mushaqar were higher than those at Maru (Table 6).

Table 10: Main effects of planting dates, nitrogen fertilizer levels and seeding rates on yield components of cumin grown at Maru during the growing season of 2004/2005.

Planting date	Branch plant^{-1}	Umbels plant^{-1}	Seed umbrella^{-1}	Seed plant^{-1}	1000 seed weight (gm)
Dec. 1, 2004	2.98	13.04	26.06	344.1	2.83
Dec. 29, 2004	2.39	8.32	25.43	212.4	3.16
Jan. 31, 2005	2.40	10.50	21.14	222.5	3.37
LSD	0.11	0.48	1.54	42.9	0.08
Nitrogen level (kg N ha^{-1})					
0	2.49	10.13	24.19	250.9	3.15
20	2.58	10.69	24.12	258.3	3.09
40	2.71	11.04	24.32	269.7	3.01
LSD	0.10	0.53	0.63	19.7	0.06
Seeding rate (kg ha^{-1})					
15	2.92	11.52	24.40	285.3	3.14
20	2.66	10.76	23.78	257.3	3.19
25	2.44	10.50	23.42	249.9	3.09
30	2.34	9.71	25.24	246.1	3.06
LSD	0.09	0.50	0.84	18.6	0.07

Table 11: Main effects of planting dates, N fertilizer levels and seeding rates on yield components of cumin sown at Mushaqar during the growing season of 2004/2005.

Planting date	Branch plant^{-1}	Umbel plant^{-1}	Seed umbrella^{-1}	Seed plant^{-1}	1000 seed weight (gm)
Dec. 30, 2004	2.31	12.18	10.26	126.9	2.67
Jan. 17, 2005	2.44	11.83	12.39	146.0	2.72
LSD	0.07	2.16	4.43	78.7	0.32
Nitrogen level (kg N ha^{-1})					
0	2.24	11.41	11.40	131.2	2.72
20	2.30	11.83	11.26	133.3	2.72
40	2.59	12.78	11.32	144.7	2.65
LSD	0.18	1.83	1.36	29.6	0.09
Seeding rate (kg ha^{-1})					
15	2.61	12.93	11.49	150.8	2.71
20	2.48	12.14	11.05	131.5	2.72
25	2.28	11.43	11.62	134.6	2.67
30	2.13	11.52	11.14	128.8	2.68
LSD	0.13	1.61	1.36	22.6	0.09

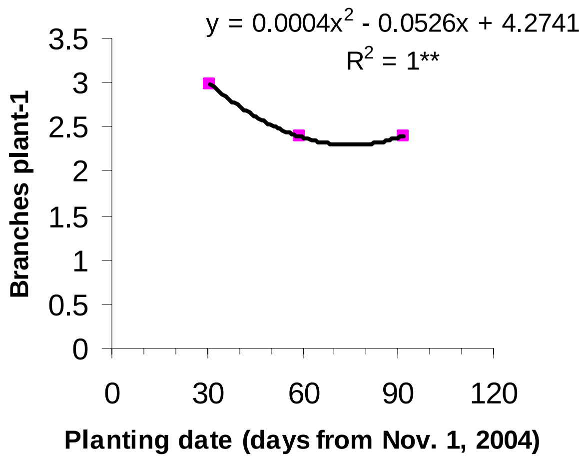

Figure 8: Relationship between planting dates and number of branches per plant at Maru ** = significant at 1%.

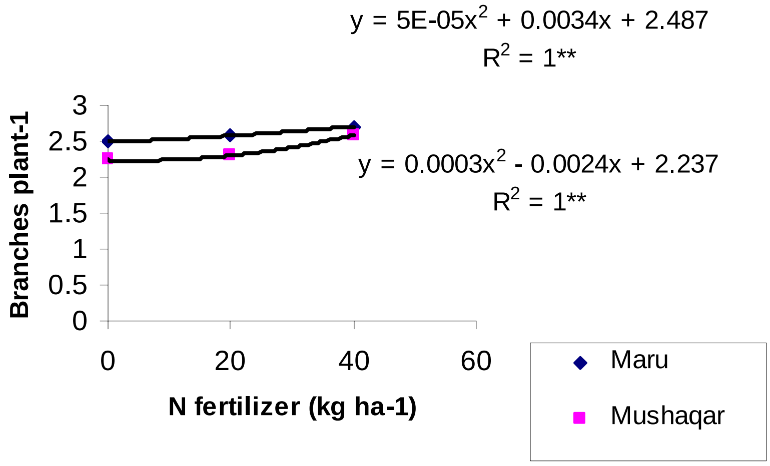

Figure 9: Relationship between nitrogen fertilizer levels and number of branches per plant at Maru and Mushaqar. ** = significant at 1%.

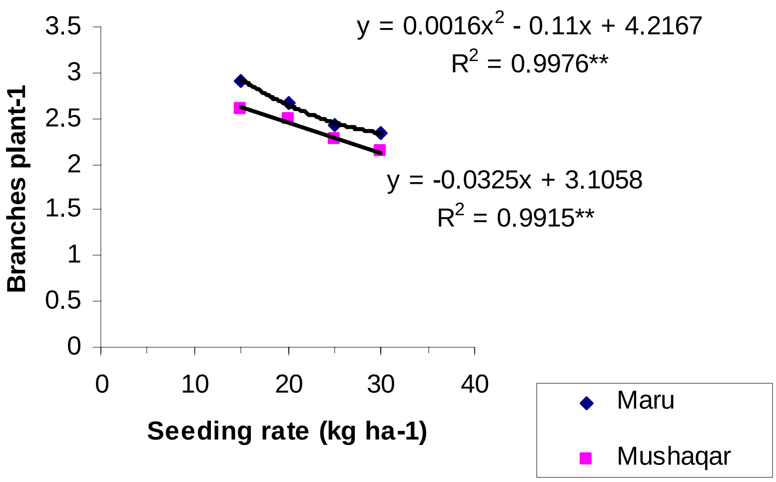

Figure 10: Relationship between seeding rates and number of branches per plant at Maru and Mushaqar. ** = significant at 1%.

Table 12: Interaction effects of planting dates and N fertilizer levels on number of main branches per plant of cumin sown at Maru location during the growing season of 2004/2005.

Planting date	Nitrogen level (kg N ha^{-1})		
	0	20	40
Dec. 1, 2004	2.95	2.89	3.11
Dec. 29, 2005	2.16	2.41	2.59
Jan. 31, 2005	2.35	2.43	2.42

LSD at 5% = 0.17 branch.

Table 13: Interaction effects of planting dates and seeding rates on number of main branches per plant of cumin grown at Maru location during the growing season of 2004/2005.

Seeding rate (kg ha^{-1})	Planting date		
	Dec. 1, 2004	Dec. 29, 2004	Jan. 31, 2005
15	3.17	2.92	2.67
20	3.03	2.43	2.52
25	2.89	2.08	2.36
30	2.86	2.13	2.04

LSD at 5% = 0.16 branch.

Table 14: Interaction effects of N fertilizer levels and seeding rates on number of main branches per plant of cumin grown at Maru location during the growing season of 2004/2005.

Seeding rate (kg ha^{-1})	Nitrogen level (kg N ha^{-1})		
	0	20	40
15	2.76	2.87	3.12
20	2.55	2.72	2.72
25	2.46	2.27	2.59
30	2.18	2.46	2.39

LSD at 5% = 0.17 branch.

Table 15: Interaction effects of planting dates, N fertilizer levels and seeding rates on number of main branches per plant of cumin grown at Maru during the growing season of 2004/2005.

Planting date	Nitrogen level (kg N ha^{-1})	Seeding rate (kg ha^{-1})			
		15	20	25	30
Dec. 1, 2004	0	3.07	3.07	3.13	2.53
	20	3.10	3.03	2.43	3.00
	40	3.33	3.00	3.07	3.03
Dec. 29, 2004	0	2.45	2.15	2.10	1.95
	20	2.90	2.45	1.90	2.40
	40	3.40	2.70	2.25	2.03
Jan. 31, 2005	0	2.77	2.43	2.13	2.07
	20	2.60	2.67	2.47	1.97
	40	2.63	2.47	2.47	2.10

LSD at 5% = 0.28 branch.

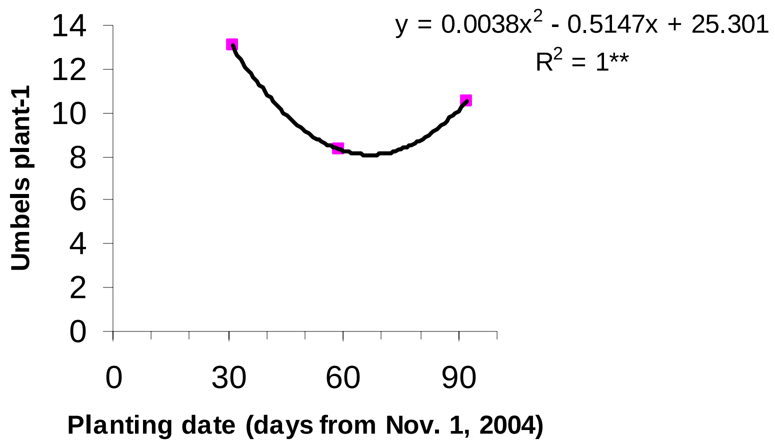

Figure 11: Relationship between planting dates and number of umbels per plant at Maru
** = significant at 1%.

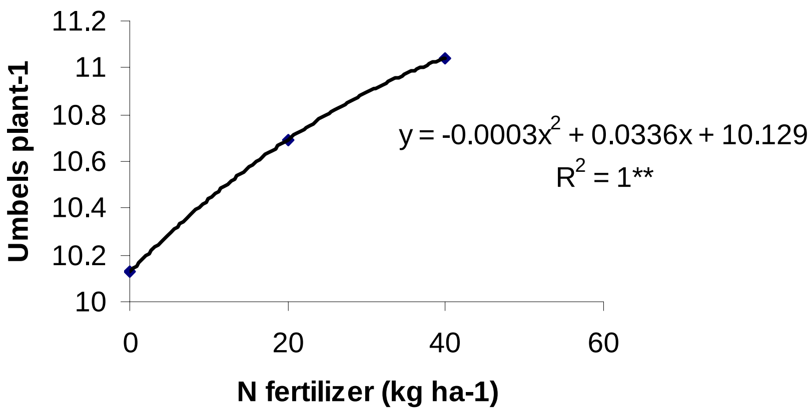

Figure 12: Relationship between nitrogen fertilizer levels and number of umbels per plant at Maru. ** = significant at 1%.

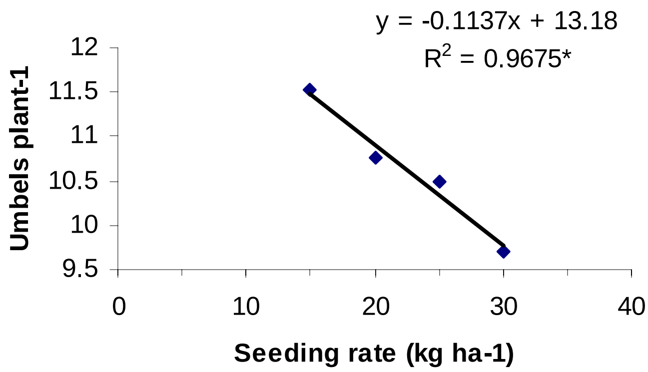

Fig. 13: Relationship between seeding rates and number of umbels per plant at Maru.
* = significant at 5%.

Table 16: Interaction effects of planting dates and N fertilizer levels on number of umbels per plant of cumin grown at Maru location during the growing season of 2004/2005.

Planting date	Nitrogen level (kg N ha^{-1})		
	0	20	40
Dec. 1, 2004	13.24	13.15	12.72
Dec. 29, 2004	7.22	8.04	9.70
Jan. 31, 2005	9.92	10.89	10.72

LSD at 5% = 0.82 umbrella.

Table 17: Interaction effects of planting dates and seeding rates on number of umbels per plant of cumin grown at Maru location during the growing season of 2004/2005.

Seeding rate (kg ha^{-1})	Planting date		
	Dec. 1, 2004	Dec. 29, 2004	Jan. 31, 2005
15	14.03	10.08	10.43
20	12.63	8.78	10.86
25	12.86	7.05	11.60
30	12.63	7.37	9.12

LSD at 5% = 0.83 umbrella.

Table 18: Interaction effects of planting dates, N fertilizer levels and seeding rates on number of umbels per plant of cumin grown at Maru location during the growing season of 2004/2005.

Planting date	Nitrogen fertilizer level (kg N ha^{-1})	Seeding rate (kg ha^{-1})			
		15	20	25	30
Dec. 1, 2004	0	14.87	13.23	13.13	11.73
	20	14.47	11.90	11.77	14.47
	40	12.77	12.77	13.67	11.70
Dec. 29, 2004	0	7.60	8.15	6.30	6.85
	20	9.90	9.10	5.70	7.45
	40	12.75	9.10	9.15	7.80
Jan. 31, 2005	0	10.53	9.85	10.27	9.03
	20	10.03	12.00	13.53	8.00
	40	10.73	10.73	11.00	10.33

LSD at 5% = 1.51 umbrella.

4.2.3 Number of seeds per umbrella

At Maru location, number of seeds per umbrella was significantly affected by planting date, seeding rate and the interactions between planting dates and nitrogen fertilizer levels; seeding rates and planting dates; and the interaction between planting dates, nitrogen fertilizer levels and seeding rates (Appendix A-6). While at Mushaqar location, there were no significant differences for number of seeds per umbrella among planting dates, nitrogen fertilizer levels, seeding rates or their interactions except the interaction between nitrogen fertilizer levels and seeding rates (Appendix A-16).

At Maru, early sowing on December 1 resulted in 2.5% and 23.3% more seeds per umbrella as compared to sowing on December 29 and on January 31, respectively (Table 10). While at Mushaqar, delaying sowing from December 30 to January 17 increased number of seeds per umbrella by about 20.7% (Table 11). The relationship between planting dates and number of seeds per umbrella at Maru was curvilinear and highly significant (Fig. 14).

Nitrogen fertilization have no significant effects on number of seeds per umbrella at both locations, however, the highest number of seeds per umbrella at Maru was with 40 kg nitrogen ha^{-1}, and the lowest value was with 20 kg nitrogen ha^{-1} (Table 10), while at Mushaqar, plants received no nitrogen fertilizer gave the highest number of seeds per umbrella, and the lowest number was for plants received 20 kg nitrogen ha^{-1} (Table 11).

The highest number of seeds per umbrella at Maru was recorded when the crop was sown at a rate of 30 kg ha^{-1}, and the lowest value was under 25 kg seeds ha^{-1}. While at Mushaqar, the highest number of seeds per umbrella was when the crop was sown at a rate of 25 kg ha^{-1}, and the lowest value was at a rate of 20 kg seeds ha^{-1}(Tables 10 and 11). The relationship between seeding rates and number of seeds per umbrella at Maru was curvilinear and significant (Fig. 15).

Interaction effects of planting dates and nitrogen fertilizer levels on number of seeds per umbrella at Maru are presented in Table 19. The highest number of seeds per umbrella was obtained when plants sown on December 1 without nitrogen fertilization, which gave 34% higher than the lowest number which was obtained when plants was sown on January 31 without nitrogen fertilization.

Interaction effects of planting dates and seeding rates on number of seeds per umbrella at Mara are presented in Table 20. The best combination that gave the highest number of seeds per umbrella was sowing on December 29 with 30 kg seeds ha^{-1}, which was 40% higher than the lowest number obtained when sowing was on January 31 with 20 kg seeds ha^{-1}.

Interaction effects of planting dates, nitrogen fertilizer levels, and seeding rates on number of seeds per umbrella at Mara are presented in Table 21. Plants sown on December 29 with 30 kg seeds ha^{-1} and received 20 kg nitrogen ha^{-1} gave the highest number of seeds per umbrella, which was 64% higher than the lowest number which was obtained when plants were sown on January 31 at a seeding rate of 25 kg ha^{-1} and without nitrogen fertilization.

Interaction effects of nitrogen fertilizer levels and seeding rates on number of seeds per umbrella at Mushaqar are presented in Table 22. The highest number of seeds per umbrella was obtained when the crop was sown at a seeding rate of 15 kg ha^{-1} with 40 kg nitrogen ha^{-1}, and the lowest value was when the crop was sown at 20 kg seeds ha^{-1} with 40 kg nitrogen ha^{-1}.

Over the two locations, there was significant difference in number of seeds per umbrella; the highest value was at Mara location, which was about 106% higher than that at Mushaqar (Table 6).

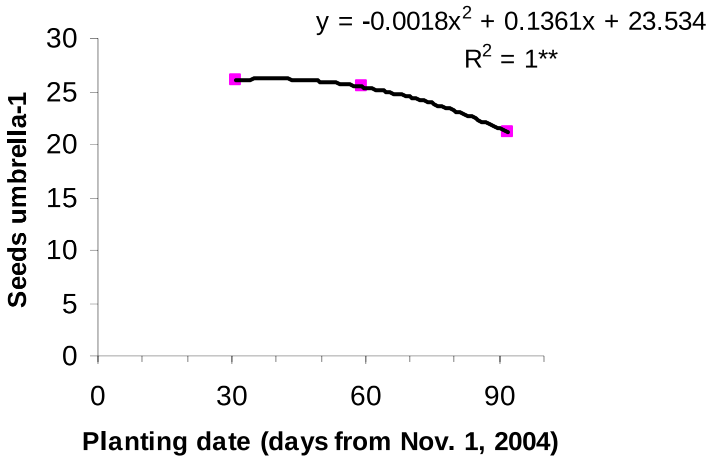

Figure 14: Relationship between planting dates and number of seeds per umbrella at Maru ** = significant at 1%.

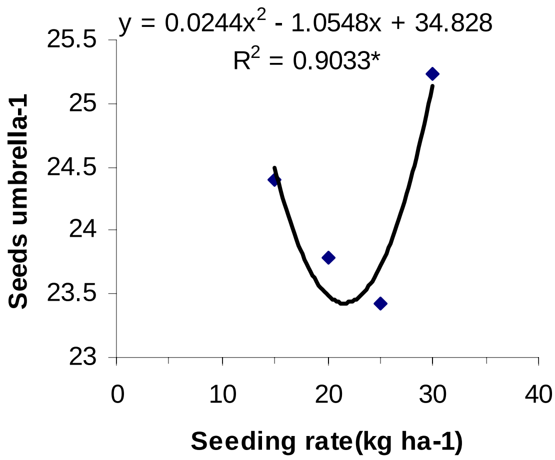

Figure 15: Relationship between seeding rates and number of seeds per umbrella at Maru. * = significant at 5%.

Table 19: Interaction effects of planting dates and N fertilizer levels on number of seeds per umbrella of cumin grown at Maru location during the growing season of 2004/2005.

Planting date	Nitrogen fertilizer level (kg N ha^{-1})		
	0	20	40
Dec. 1, 2004	27.17	24.37	26.65
Dec. 29, 2004	25.08	25.95	25.25
Jan. 31, 2005	20.32	22.05	21.06

LSD at 5% = 1.56 seed.

Table 20: Interaction effects of planting dates and seeding rates on number of Seeds per umbrella of cumin grown at Maru location during the growing season of 2004/2005.

Seeding rate (kg ha^{-1})	Planting date		
	Dec. 1, 2004	Dec. 29, 2004	Jan. 31, 2005
15	27.11	24.83	21.26
20	25.29	25.72	20.34
25	26.09	23.05	21.13
30	25.76	28.12	21.84

LSD at 5% = 1.75 seed.

Table 21: Interaction effects of planting dates, N fertilizer levels and seeding rates on number of seeds per umbrella of cumin grown at Maru location during 2004/2005 season.

Planting date	N fertilizer level (kg N ha^{-1})	Seeding rate (kg ha^{-1})			
		15	20	25	30
Dec. 1, 2004	0	28.07	25.93	27.60	27.07
	20	25.13	22.93	25.60	23.80
	40	28.13	27.00	25.07	26.40
Dec. 29, 2004	0	25.50	24.93	22.90	27.00
	20	26.49	24.57	21.84	30.90
	40	22.50	27.65	24.40	26.45
Jan. 31, 2005	0	19.67	21.07	18.83	21.70
	20	23.33	20.43	22.83	21.62
	40	20.77	19.53	21.73	22.20

LSD at 5% = 2.57 seed.

Table 22: Interaction effects of N fertilizer levels and seeding rates on number of seeds per umbrella for cumin grown at Mushaqar location during the growing season of 2004/2005.

Seeding rate (kg ha^{-1})	Nitrogen fertilizer level (kg N ha^{-1})		
	0	20	40
15	10.18	10.31	13.97
20	10.35	12.80	10.00
25	12.93	11.13	10.78
30	12.12	10.79	10.52

LSD at 5% = 2.51 seed.

4.2.4 Number of seeds per plant

At Maru location, number of seeds per plant was significantly affected by planting dates, seeding rates, interactions between planting dates and nitrogen fertilizer levels, planting dates and seeding rates and the interaction between planting date, nitrogen fertilizer levels and seeding rate (Appendix A-7). While at Mushaqar, seeds per plant were only affected by the interactions between nitrogen fertilizer levels and seeding rates and the interaction between planting dates, nitrogen fertilizer levels and seeding rates (Appendix A-17).

At Maru, the highest number of seeds per plant was obtained when the crop was sown on December 1 which gave 62% higher number of seeds plant^{-1} than the lowest number obtained when the crop was sown on December 29 (Table 10). The relationship between planting dates and number of seeds per plant was curvilinear and highly significant (Figure 16). At Mushaqar, delaying sowing from December 30 to January 17 increased number of seeds per plant by about 15% (Table 11).

Nitrogen fertilization has no significant effect on number of seeds per plant at both locations, however, the trend show that increasing nitrogen fertilizer level increased number of seeds per plant (Tables 10 and 11).

Increasing plant density decreased number of seeds per plant. At Maru the highest number of seeds per plant was when the crop was sown at a rate of 15 kg ha^{-1} which gave about 16% higher than the lowest number obtained at seeding rate of 30 kg ha^{-1} (Table 10). While at Mushaqar, the highest number of seeds per plant was obtained at a seeding rate of 15 kg ha^{-1} which was higher by 17% than the lowest number which was recorded at 30 kg seeds ha^{-1} (Table 11). The relationship between seeding rates and number of seeds per plant was curvilinear and highly significant at Maru (Fig. 17).

Interaction effects of planting dates and N fertilizer levels on number of seeds per plant at Maru are presented in Table 23. The highest number of seeds was for plants sown on December 1 without fertilization, and the lowest number was for plants sown on December 29 without fertilization.

Interaction effects of planting dates and seeding rates on number of seeds per plant at Maru are presented in Table 24. Plants sown on December 1 with 15 kg seeds ha^{-1} gave the highest number of seeds per plant, while the lowest value was for plants sown on December 29 with 25 kg seeds ha^{-1}.

Interaction effects of planting dates, N fertilizer levels and seeding rates on number of seeds per plant at Maru are presented in Table 25. The best combination that gave the highest number of seeds per plant was when the crop was sown on December 1 at a seeding rate of 15 kg ha^{-1} without N fertilization, and the lowest number was obtained when sowing on December 29 at a seeding rate of 25 kg ha^{-1} with 20 kg N ha^{-1}.

Interaction effects of N fertilizer levels and seeding rates on number of seeds per plant at Mushaqar are presented in Table 26. The highest number of seeds was obtained for plants sown at 15 kg seeds ha^{-1} and received 40 kg N ha^{-1}, while the lowest value was for plants sown at 25 kg seeds ha^{-1} and received 40 kg N ha^{-1}.

Interaction effects of planting dates, N fertilizer levels and seeding rates on number of seeds per plant at Mushaqar are presented in Table 27. The best combination that gave the highest number of seeds per plant was obtained when sowing on December 30 at a seeding rate of 15 kg ha^{-1} and with 40 kg N ha^{-1}, while the lowest number was recorded for plants sown on December 30 at a rate of 30 kg seeds ha^{-1} and without N fertilization.

Over the two locations, seeds per plant at Maru were significantly greater than that at Mushaqar by about 59.3% (Table 6).

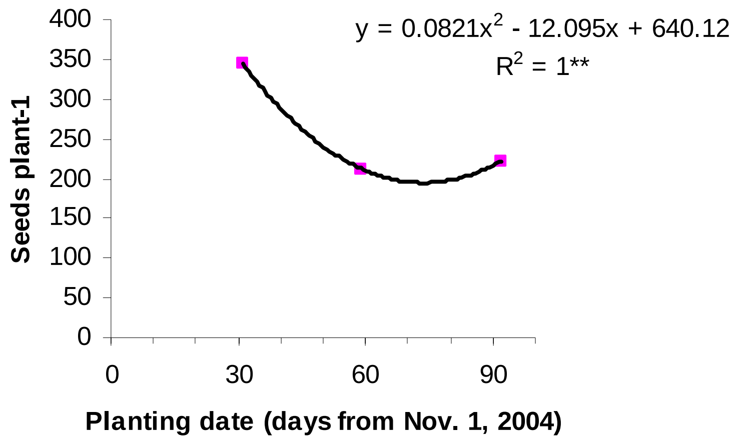

Figure 16: Relationship between planting dates and number of seeds per plant at Maru
** = significant at 1%.

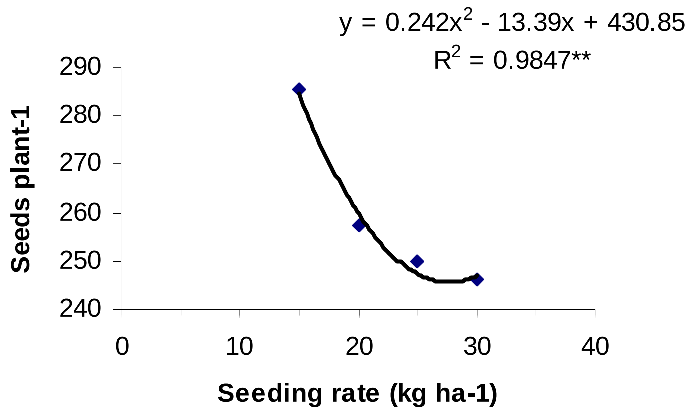

Figure 17: Relationship between seeding rates and number of seeds per plant at Maru.
** = significant at 1%.

Table 23: Interaction effects of planting dates and N fertilizer levels on number of seeds per plant of cumin grown at Maru location during the growing season of 2004/2005.

Planting date	Nitrogen fertilizer level (kg N ha^{-1})		
	0	20	40
Dec. 1, 2004	368.1	324.7	339.5
Dec. 29, 2004	183.2	210.6	243.3
Jan. 31, 2005	201.5	239.5	226.5

LSD at 5% = 44.8 seed.

Table 24: Interaction effects of planting dates and seeding rates on number of seeds per plant of cumin grown at Maru location during the growing season of 2004/2005.

Seeding rate ($kg\ ha^{-1}$)	Planting date		
	Dec. 1, 2004	Dec. 29, 2004	Jan. 31, 2005
15	384.8	249.0	222.1
20	324.4	227.7	219.7
25	337.3	164.7	247.7
30	329.7	208.1	200.6

LSD at 5% = 45.1 seed.

Table 25: Interaction effects of planting dates, N fertilizer levels and seeding rates on number of seeds per plant of cumin grown at Maru location during the growing season of 2004/2005.

Planting date	Nitrogen level ($kg\ N\ ha^{-1}$)	Seeding rate ($kg\ ha^{-1}$)			
		15	20	25	30
Dec. 1, 2004	0	432.0	345.7	362.7	332.0
	20	362.8	282.3	306.3	347.3
	40	359.7	345.3	343.0	309.8
Dec. 29, 2004	0	196.0	203.7	145.3	187.8
	20	263.3	244.0	125.0	230.2
	40	287.7	255.3	223.8	206.3
Jan. 31, 2005	0	207.3	209.0	193.7	196.2
	20	235.3	240.2	309.0	173.7
	40	223.5	210.0	240.3	232.0

LSD at 5% = 63.2 seed.

Table 26: Interaction effects of N fertilizer levels and seeding rates on number of seeds per plant of cumin grown at Mushaqar location during the growing season of 2004/2005.

Seeding rate (kg ha^{-1})	Nitrogen fertilizer level (kg N ha^{-1})		
	0	20	40
15	115.2	126.1	211.1
20	122.4	143.8	128.4
25	158.5	131.8	113.4
30	128.9	131.6	126.1

LSD at 5% = 42.8 seed.

Table 27: Interaction effects of planting dates, N fertilizer levels and seeding rates on number of seeds per plant of cumin grown at Mushaqar location during the growing season of 2004/2005.

Planting date	Nitrogen level (kg N ha^{-1})	Seeding rate (kg ha^{-1})			
		15	20	25	30
Dec. 30, 2004	0	108.8	100.6	185.5	83.5
	20	118.8	125.5	128.7	102.0
	40	234.6	112.1	92.4	130.1
Jan. 17, 2005	0	121.6	144.2	131.5	174.3
	20	133.4	162.1	134.8	161.2
	40	187.5	144.7	134.4	122.2

LSD at 5% = 70.3 seed.

4.2.5 Weight of 1000 seeds

At Maru location, weight of 1000 seed was significantly affected by planting dates, seeding rates (Table 10), and the interaction between planting dates and N fertilizer levels (Table 28), but was not affected by N fertilization. While at Mushaqar the weight of 1000 seed was not affected by any of the treatments or their interactions (Table 11).

At Maru, the increase in 1000 seed weight for plants sown on January 31 was about 19% and 6.6% over those sown on December 1 and December 29 respectively, while the increase at Mushaqar was about 1.9% for plants sown on January 17 over those sown on December 30. The relationship between planting dates and weight of 1000 seed at Maru was curvilinear and highly significant (Fig. 18).

Nitrogen fertilization decreased the weight of 1000 seeds at both locations; however, the decrease was not significant. The highest weight of 1000 seeds was recorded for plants without N fertilization while the lowest value was for plants received 40 kg N ha^{-1} (Tables 10 and 11).

At Maru, the highest weight of 1000 seeds was obtained with 20 kg seeds ha^{-1} which was not different from that obtained with 15 kg seeds ha^{-1}, but higher than the lowest weight obtained at 30 kg seeds ha^{-1} by about 4% (Table 10). While at Mushaqar, the highest weight was obtained with 20 kg seeds ha^{-1} and the lowest was with 25 kg seeds ha^{-1}, however, the differences were not significant (Table 11). The relationship between seeding rates and weight of 1000 seeds at Maru was curvilinear but it was non significant (Fig. 19).

Interaction effects of planting dates and N fertilizer levels on 1000 seed weight at Mara are presented in Table 28, which indicates that the highest 1000 seed weight was for plants sown on January 31 and received 40 kg N ha^{-1}, and the lowest weight was for plants sown on December 1 and received 20 kg N ha^{-1}. Over the two locations, there was significant difference in weight of 1000 seed weight. Weight of 1000 seeds at Mara was higher than that at Mishear by about 21% (Table 6).

4.3.1 Plant height:

Main effects of planting dates, N fertilizer levels and seeding rates on plant height of cumin at Maru and Mushaqar are presented in Table 29. The three treatments and their interactions have significant effects on plant height at both locations.

At Maru, plants sown on December 1 were significantly the tallest, with about 21.5% and 29.8% taller than those sown on December 29 and January 31, respectively. At Mushaqar, delaying sowing from December 30 to January 17 decreased plant height by about 14.4%. The relationship between planting date and plant height at Maru was curvilinear and highly significant (Fig. 20).

Tallest plants were recorded with 40 kg N ha^{-1} at both locations. At Maru, plants received 40 kg N ha^{-1} were about 9.8% taller than the shortest plants which were recorded under 20 kg N ha^{-1}. While at Mushaqar, plants received 40 kg N ha^{-1} were about 4.8% taller than the shortest plants under no N fertilizer. The relationship between N fertilizer levels and plant height was curvilinear and highly significant at both locations (Fig. 21).

At both locations, the tallest plants were recorded with seeding rate of 25 kg seeds ha^{-1}, while the shortest plants were recorded with 15 kg ha^{-1} (Table 10 and Table 11). The relationship between seeding rates and plant height was curvilinear (Fig. 22), and highly significant at Maru but not significant at Mushaqar.

Interaction effects of planting dates and N fertilizer levels on plant height are presented in Table 30 for Maru and in Table 31 for Mushaqar. At Maru, the tallest plants were recorded when sown on December 1 with 40 kg N ha^{-1}, and the shortest plants were recorded when sown on January 31 without N fertilizer application. While at Mushaqar, the tallest plants were recorded when sown on December 30 with 40 kg N ha^{-1}, and the shortest plants were sown on January 17 without N fertilizer application.

Interaction effects of planting dates and seeding rates on plant height are presented in Table 32 and Table 33 for Maru and Mushaqar, respectively. At Maru, the tallest plants were recorded when sown on December 1 at a seeding rate of 20 kg ha^{-1} and the shortest plants were recorded when sown on January 31 at a seeding rate of 15 kg ha^{-1}. While at Mushaqar, the tallest plants were recorded when sown on December 30 at a seeding rate of 25 kg ha^{-1}, and the shortest plants were for plants sown on January 17 at a seeding rate of 15 kg ha^{-1}.

Interaction effects of N fertilizer levels and seeding rates on plant height are presented in Table 34 and Table 35 for Maru and Mushaqar, respectively. At Maru, the tallest plants were found at a seeding rate of 25 kg ha^{-1} with 40 kg N ha^{-1}, and the shortest plants were at a rate of 20 kg seeds ha^{-1} and received 20 kg N ha^{-1}. At Mushaqar, the tallest plants were found at a rate of 25 kg seeds ha^{-1} with 40 kg N ha^{-1} and the shortest plants were at a rate of 15 kg seeds ha^{-1} without N fertilization.

Interaction effects of planting dates, N fertilizer levels and seeding rates on plant height are presented in Table 36 and Table 37 for Maru and Mushaqar, respectively. At Maru, plants sown on December 1 were the tallest at all N fertilizer levels and seeding rates. The tallest plants were recorded when sown on December 1, at a seeding rate of 20 kg ha^{-1} and with 40 kg N ha^{-1}.

While the shortest plants were recorded when sown on January 31, at a seeding rate of 15 kg ha^{-1} without N fertilization. At Mushaqar, the tallest plants were recorded when the crop sown on December 30, at a seeding rate of 25 kg ha^{-1} without N fertilization, while the shortest plants were recorded when sown on January 17 at a seeding rate of 15 kg ha^{-1} without N fertilization. There was no significant difference in plant height among the two Locations (Table 6).

4.3.2 Oil content (%)

Seed total extractable oil percentage was measured in two replicates (72 experimental plots) from Maru location. There were no significant differences for total oil content, essential oil content and total oil yield (kg ha^{-1}) among planting dates, N fertilizer levels, seeding rates or their interactions. However, results in Table 29 indicate that early sowing on December 1 increased total oil content by 5.8% and 15.9%, increased essential oil content by 5.7% and 15.9%, and increased total oil yield by 11.6% and 14.8% as compared to sowing on December 29 and on January 31, respectively. On the other hand, the highest total oil %, essential oil%, and total oil yield were obtained under 20 kg N ha^{-1} while the lowest values were without N fertilization. For seeding rates, the highest total oil% and essential oil% were obtained with a rate of 25 kg seeds ha^{-1}, while the lowest values were under a rate of 30 kg seeds ha^{-1}. The highest total oil yield was with 30 kg seeds ha^{-1} while the lowest value was with 15 kg seeds ha^{-1}.

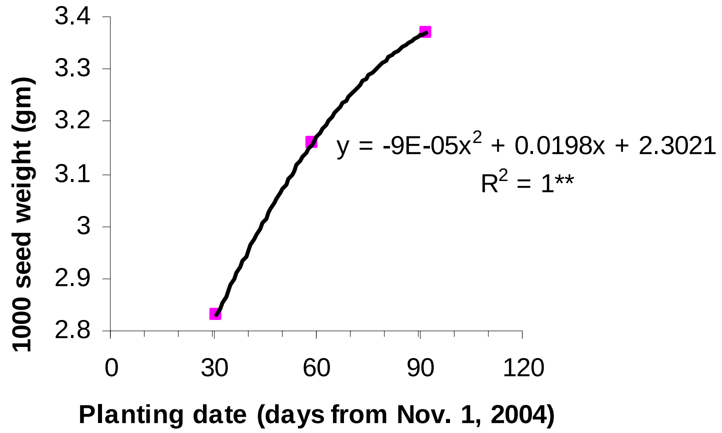

Figure 18: Relationship between planting dates and weight of 1000 seeds at Maru.
** = significant at 1%.

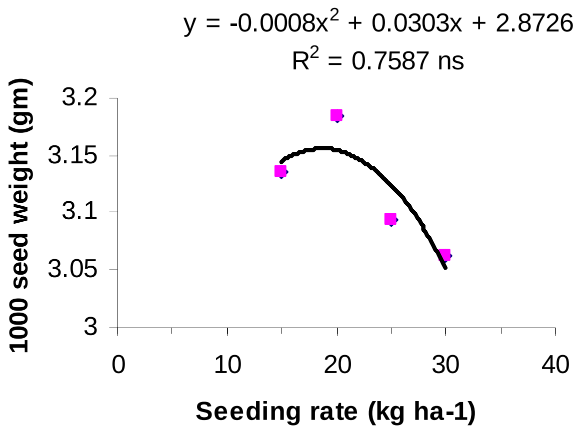

Figure 19: Relationship between seeding rates and weight of 1000 seeds at Maru.
ns = not significant at 5%.

Table 28: Interaction effects of planting dates and N fertilizer levels on weight of 1000 seeds (gm) of cumin grown at Maru location during the growing season of 2004/2005.

Planting date	Nitrogen fertilizer level (kg N ha^{-1})		
	0	20	40
Dec. 1, 2004	2.95	2.74	2.80
Dec. 29, 2004	3.18	3.17	3.13
Jan. 31, 2005	3.32	3.36	3.43

LSD at 5% = 0.11 gm.

Table 29: Main effects of planting dates, N fertilizer levels and seeding rates on plant height (cm), total oil%, essential oil% and oil yield (kg ha^{-1}) of cumin grown at Maru and Mushaqar during the growing season of 2004/2005.

Planting date	Plant height (cm)		Total oil content (%)	Oil yield (kg ha^{-1})	Essential oil content (%)
	Maru	Mushaqar	Maru	Maru	Maru
D1	20.91	----*----	12.02	87.4	2.40
D2	17.22	18.11	11.36	78.3	2.27
D3	16.11	15.47	10.37	76.1	2.07
LSD	1.88	0.52	2.91	64.3	0.58
Nitrogen level (kg N ha^{-1})					
0	17.72	16.48	11.09	65.1	2.22
20	17.41	16.62	11.45	92.3	2.29
40	19.11	17.27	11.20	84.4	2.24
LSD	0.90	0.29	0.92	29.7	0.18
Seeding rate (kg ha^{-1})					
15	17.43	16.28	11.13	71.0	2.23
20	18.13	16.60	11.02	79.0	2.20
25	18.44	17.49	11.86	85.7	2.37
30	18.33	16.79	10.98	86.7	2.20
LSD	0.47	0.29	0.82	18.1	0.16

D: planting date, for Maru, D1: December 1, 2004, D2: December 29, 2004 and D3: January 31, 2005. For Mushaqar, D2: December 30, 2004 and D3: January 17, 2005.
* First planting date at Mushaqar was damaged by frost.

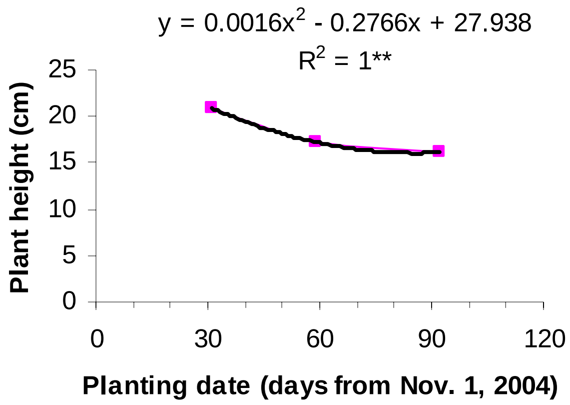

Figure 20: Relationship between planting dates and plant height at Maru.
** = significant at 1%.

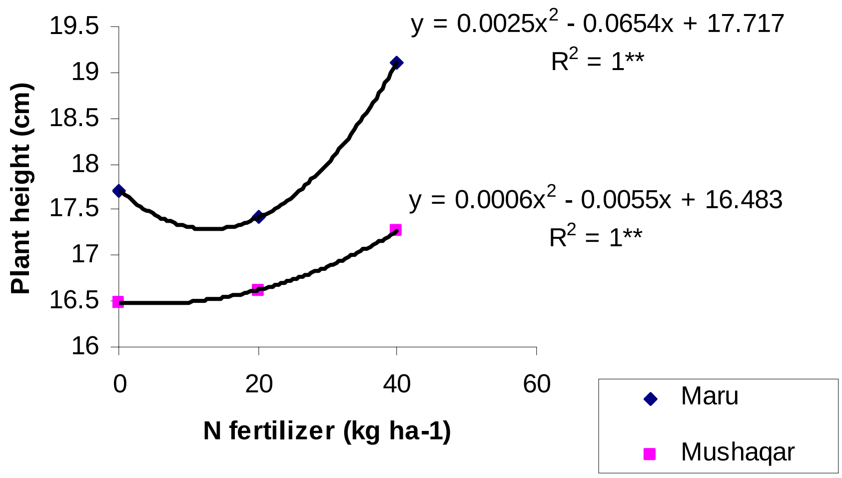

Figure 21: Relationship between nitrogen fertilizer levels and plant height at Maru and Mushaqar. ** = significant at 1%.

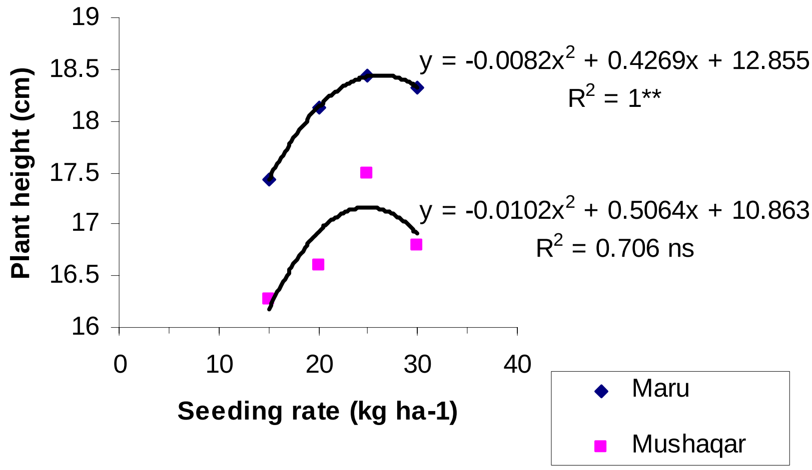

Figure 22: Relationship between seeding rates and plant height at Maru and Mushaqar.
** = significant at 1%, ns = not significant.

Table 30: Interaction effects of planting dates and N fertilizer levels on plant height (cm) of cumin grown at Maru location during the growing season of 2004/2005.

Planting date	Nitrogen fertilizer level (kg N ha^{-1})		
	0	20	40
Dec. 1, 2004	21.57	19.04	22.11
Dec. 29, 2004	16.83	16.63	18.21
Jan. 31, 2005	14.75	16.56	17.02

LSD at 5% = 1.98 cm.

Table 31: Interaction effects of planting dates and N fertilizer levels on plant height (cm) of cumin grown at Mushaqar location during the growing season of 2004/2005.

Planting date	Nitrogen fertilizer level (kg N ha^{-1})		
	0	20	40
Dec. 30, 2004	17.96	18.04	18.34
Jan. 17, 2005	15.00	15.20	16.19

LSD at 5% = 0.44 cm.

Table 32: Interaction effects of planting dates and seeding rates on plant height (cm) of cumin grown at Maru location during the growing season of 2004/2005.

Seeding rate (kg ha^{-1})	Planting date		
	Dec. 1, 2004	Dec. 29, 2004	Jan. 31, 2005
15	19.71	16.61	15.96
20	21.61	16.77	16.01
25	21.08	17.74	16.49
30	21.23	17.77	15.98

LSD at 5% = 1.83 cm.

Table 33: Interaction effects of planting dates and seeding rates on plant height (cm) of cumin grown at Mushaqar location during the growing season of 2004/2005.

Planting date	Seeding rate (kg ha^{-1})			
	15	20	25	30
Dec. 30, 2004	17.88	18.06	18.33	18.17
Jan. 17, 2005	14.67	15.14	16.64	15.42

LSD at 5% = 0.45 cm.

Table 34: Interaction effects of seeding rates and N fertilizer levels on plant height (cm) of cumin grown at Maru location during the growing season of 2004/2005.

Seeding rate (kg ha^{-1})	Nitrogen fertilizer level (kg N ha^{-1})		
	0	20	40
15	16.88	17.34	18.06
20	18.08	17.23	19.08
25	18.34	17.28	19.69
30	17.57	17.79	19.62

LSD at 5% = 1.10 cm.

Table 35: Interaction effects of N fertilizer levels and seeding rates on plant height(cm) of cumin grown at Mushaqar location during the growing season of 2004/2005.

Nitrogen level (kg N ha^{-1})	Seeding rate (kg ha^{-1})			
	15	20	25	30
0	15.69	16.18	17.76	16.31
20	16.33	16.82	16.63	16.70
40	16.81	16.80	18.07	17.37

LSD at 5% = 0.50 cm.

Table 36: Interaction effects of planting dates, N fertilizer levels and seeding rates on plant height (cm) of cumin grown at Maru location during the growing season of 2004/2005.

Planting date	Nitrogen level (kg N ha^{-1})	Seeding rate (kg ha^{-1})			
		15	20	25	30
Dec. 1, 2004	0	20.60	22.70	21.67	21.33
	20	17.50	19.43	19.13	20.10
	40	21.03	22.70	22.43	22.27
Dec. 29, 2004	0	16.20	16.27	17.60	17.23
	20	17.27	15.77	16.27	17.23
	40	16.37	18.26	19.36	18.83
Jan. 31, 2005	0	13.83	15.27	15.76	14.13
	20	17.26	16.50	16.43	16.03
	40	16.77	16.27	17.26	17.77

LSD at 5% = 2.25 cm.

Table 37: Interaction effects of planting dates, N fertilizer levels and seeding rates on plant height (cm) of cumin grown at Mushaqar location during the growing season of 2004/2005.

Planting date	Nitrogen level (kg N ha^{-1})	Seeding rates (kg ha^{-1})			
		15	20	25	30
Dec. 30, 2004	0	17.23	17.60	18.77	18.25
	20	17.75	18.42	18.33	17.67
	40	18.68	18.17	17.90	18.60
Jan. 17, 2005	0	14.15	14.75	16.75	14.37
	20	14.92	15.23	14.93	15.73
	40	14.93	15.43	18.25	16.15

LSD at 5% = 0.73 cm.

4.4 Days to emergence, days to flowering, days to maturity, and the accumulated heat units

4.4.1 Days to emergence

Number of days and accumulated heat units required to emergence, to flowering and to maturity are presented in Table 38. At both locations the longest period required to emergence was for plants sown on late December. At Maru, the number of days needed to emergence among plants sown on December 1 and January 31 was very close. The accumulated heat units needed to emergence at Maru were increased by early sowing; an increase of 73% and 90.7% for plants sown on December 1 as compared to those sowing on December 29 and January 31, respectively. At Mushaqar, delaying sowing from December 2 to December 30 increased the accumulated heat units required to emergence by 62%, but delaying sowing to January 17 decreased it by 18%.

4.4.2 Days to flowering

Numbers of days needed to flowering starting from emergence date were varied largely by sowing dates; it decreased by delaying sowing at both locations. At Maru, delaying sowing from December 1 to December 29 and January 31 decreased the period required to flowering by 27.6% and 43.8%, respectively, while the accumulated heat units required to flowering decreased by 10.9% and 6.3%, respectively. At Mushaqar, delaying sowing from December 30 to January 17 reduced the period by 10%, but increased the accumulated heat units by 15.4%.

4.4.3 Days to maturity

Numbers of days required to maturity starting from emergence dates were decreased with delaying sowing at both locations (Fig. 23). But delaying sowing decreased the accumulated heat units at Maru (Fig. 24), and increased at Mushaqar. At Maru, delaying sowing from December 1 to December 29 and January 31 decreased the period required to maturity by 20.6% and 36.6%, respectively, and decreased the heat units by 3.7% and 6.4%, respectively. At Mushaqar, delaying sowing from December 39 to January 17 decreased the period required to maturity by 7.3%, but increased the accumulated heat units by 8.6%.

4.5 Correlation among the studied characters

The correlation coefficient values (r) among the studied characters are presented in Table 39, the r values for Mushaqar are between brackets to facilitate the comparison between the two locations. In this section we will presents the highly significant coefficient of determination (r^2).

The highest association was found between grain yield and biological yield at both locations (r^2 = 0.88 and 0.84 for Maru and Mushaqar, respectively). Grain yield was positively and significantly correlated with yield component characters at Maru but not at Mushaqar location, except for 1000 seed weight where the correlation was negative. The r^2 values for different associations were 0.16 for number of branches plant^{-1}, 0.08 for number of umbels plant^{-1}, 0.24 for number of seeds umbrella^{-1}, 0.19 for number of seeds plant^{-1}, and 0.26 for 1000 seed weight. Grain yield was also significantly correlated with plant height at Maru location with r^2 value of 0.28. Harvest index was correlated with grain yield at Mushaqar (r^2 = 0.19), but not at Maru. Similar trend to grain yield, biological yield was also correlated with the other traits at Maru but not at Mushaqar, with r^2 values close to what was reported earlier with grain yield.

The most important correlations among yield components are between branches number with number of umbels plant^{-1}, seeds umbrella^{-1}, seeds plant^{-1}, and with a negative correlation with 1000 seed weight. In fact, 1000 seed weight has a negative correlation with almost all the studied traits. Moreover, 1000 seed weight has a negative and significant correlation with oil content with r^2 value of 0.11.

Table 38: Number of days and accumulated heat units required to emergence, to flowering and to maturity of cumin grown at Maru and Mushaqar during the growing season of 2004/2005.

	Maru			Mushaqar		
Planting date	Dec. 1, 2004	Dec. 29, 2004	Jan. 31, 2005	Dec. 2, 2004	Dec. 30, 2004	Jan. 17, 2005
Emergence date	Dec. 27, 2004	Jan. 29, 2005	Feb. 27, 2005	Dec. 27, 2004	Jan. 31, 2005	Feb. 15, 2005
Days to emergence (days)*	27	32	28	26	33	30
Heat units to emergence	225	130	118	77	125	63
Flowering date	Apr. 10, 2005	Apr. 15, 2005	Apr. 26, 2005	---**---	Apr. 19, 2005	Apr. 27, 2005
Days to flowering (days)*	105	76	59	----**---	79	71
Heat units to flowering	603	537	565	----**---	544	628
Maturity date	May 6, 2005	May 13, 2005	May 20, 2005	----**---	May 20, 2005	May 27, 2005
Days to maturity (days)*	131	104	83	----**---	110	102
Heat units to maturity	930	895	870	----**---	950	1032

* Starting from date of emergence.
** Plants of the first planting date were damaged by frost, so no data recorded.

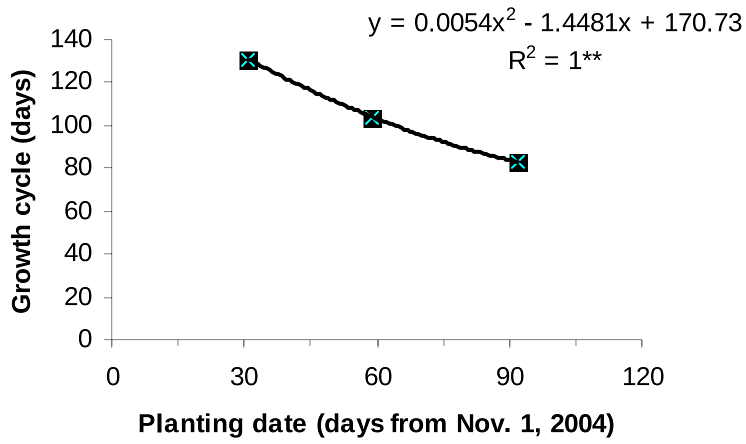

Figure 23: Relationship between planting date and number of days required to maturity starting from seed emergence (growth cycle) at Maru. ** = significant at 1%.

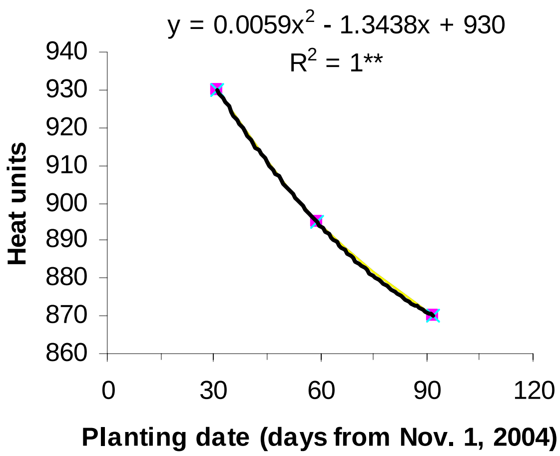

Figure 24: Relationship between planting date and accumulated heat units at Maru.

** = significant at 1%.

Table 39: Coefficient of linear correlation among different plant character of cumin grown at Maru and Mushaqar during the growing season of 2004/2005.

	GY	BY	HI	Br P^{-1}	Um P^{-1}	S Um^{-1}	S p^{-1}	1000 SW	PH	Oil%
GY	1.00	0.937** (0.919**)	0.159 (0.44**)	0.399** (0.012)	0.281** (0.028)	0.494** (0.155)	0.44** (0.114)	-0.51** (-0.115)	0.533** (0.147)	0.25*
BY		1.00	-0.13 (0.105)	0.406** (-0.055)	0.279** (-0.028)	0.423** (0.155)	0.409** (0.071)	-0.532** (-0.177)	0.559** (0.128)	0.297*
HI			1.00	0.04 (0.128)	0.024 (0.182)	0.199* (0.070)	0.105 (0.183)	0.071 (0.039)	-0.036 (0.007)	-0.201
Br P^{-1}				1.00	0.708** (0.488**)	0.252** (0.21)	0.663** (0.441**)	-0.415** (-0.061)	0.439** (-0.188)	0.169
Um P^{-1}					1.00	0.250** (0.076)	0.90** (0.676**)	-0.34** (-0.127)	0.464** (0.013)	-0.053
S Um^{-1}						1.00	0.631** (0.773**)	-0.493** (0.014)	0.474** (-0.234)	0.056
S P^{-1}							1.00	-0.497** (-0.082)	0.587** (-0.125)	-0.001
1000 SW								1.00	-0.639** (-0.272*)	-0.332**
PH									1.00	0.144
Oil%										1.00

GY: grain yield, BY: biological yield, HI: harvest index, Br P^{-1}: number of branches per plant, Um P^{-1}: umbels per plant, S Um^{-1}: seeds per umbrella, S P^{-1}: seeds per plant, SW: 1000 seed weight, PH: plant height, Oil%: total seed oil content. ( ): values for Mushaqar. Number of observations was 108 for Maru, and 72 for Mushaqar.
*, **: significant at 5% and 1%, respectively.

5. Discussion

5.1 Grain yield, biological yield and harvest index

Sowing on December 1 at Maru resulted in grain yield increase of 26% and 64% as compared to sowing on December 29 and January 31, respectively. Similarly it increased biological yield by 31% and 68%, respectively (Table 3). Early sowing resulted in an extended growth period where the plant had around 131 days from emergence to maturity as compared to 104 days for plants sown on December 29 and only 83 days for plants sown on January 31 (Table 38). They also have more accumulated heat units than those recorded in the second and third planting dates. For example, the accumulated heat units from emergence to maturity for plants sown in the first planting date exceeded those in the second date by 35 units and those in the third planting date by 60 units (Table 38). The extended growth period and the higher accumulated temperatures during the growing season of the plants sown in the first planting date allow the plants to better utilize soil moisture, nutrients, and solar radiation, which resulted in more dry matter accumulation as grain yield and biological yield. This was reflected on the effect of early sowing on the yield components of the crop; early sowing at Maru resulted in an increase in the number of branches, umbels, seeds per umbrella and total number of seeds per plant (Table 3), and also taller plants (Table 29), which contributed to more grain yield and biological yield. In fact, grain yield and biological yield were positively and significantly correlated with yield components characters except for 1000 seed weight where the correlation was negative. The coefficient of determination (r^2) of these associations ranged from 0.08 for umbels $plant^{-1}$ to 0.24 for seeds $umbrella^{-1}$ (Table 39) which indicated that the direct contribution of these yield components to grain yield were substantial and important in the attempt to improve cumin grain yield. The negative correlation between grain yield and 1000 seed weight is rather expected because as numbers of seeds per plant increase the weight of the single seed tend to decrease. The relationship between grain yield and planting date in Maru was linear, negative relationship (Fig. 3). The regression equation predicts a decrease of 6.53 kg grain with each day delay in planting after December 1 which is the first planting date. Our results are in agreement with those of Bianco *et al*. (1994) in a study conducted on fennel plant in south Italy, they reported that delaying sowing from August to September decreased number of branches per plant from three to two, and decreased grain yield from 1600 to 900 kg ha^{-1}. Also our results were in line with those of Yousaf *et al*. (2002) working on canola plant at Bahawalpur, Pakistan, they reported that late planting adversely affect yield and yield components due to its effect on growth, because different growth stages required enough time for their development. For example, they reported that the best sowing date was October 11 which gave 2111 kg grain ha^{-1} as compared to 1914 kg ha^{-1} and 1806 kg ha^{-1} for those sown on October 21 and October 31, respectively.

Sowing on December 1 resulted in a relatively lower harvest index values as compared to sowing on December 29 and January 3 (Table 3), which showed that early planting contributed more to the vegetative growth than to grain production, however, the high vegetative growth in early sowing resulted in supporting more grain production and eventually more grain yield was produced. This could be also observed with the strong positive correlation between grain yield and biological yield (Table 39) and for the two locations. Biological yield has an r^2 value with grain yield of 0.84 for Mushaqar and 0.88 for Maru location which is the highest among all traits associations with grain yield. It is, however, worth mentioning that grain yield is part of biological yield and thus such strong association is expected especially if the environmental conditions and the growing season are favorable for both traits; vegetative and grain production. It is important, however, to realize that the growing season was very favorable at Maru in term of available soil moisture (428 mm annual rainfall), and prevailing temperature. It will be interesting to observe the behavior of the plants if a terminal moisture stress occurred, which is common in the rainfed areas of Jordan, which is expected to affect the magnitudes and the partitioning of the assimilates to grain and straw. Our results were in agreement with those recorded by D'Antuono *et al*. (2002), where they reported that delay sowing of black cumin from March to May increased harvest index from 28.6% to 33%.

At Mushaqar location, the results were the opposite of what have been reported at Maru. Plant growth cycle was disrupted by the effect of around zero temperature occurred on the night of March 26, which resulted in a complete damage of plants sown on December 1 and some damage to plants sown on December 30. However plants sown late on January 17 was less affected by the low temperature. Our observations that the most affected plants were those which had more vegetative growth, and therefore even the plants in the second planting date were not killed, however, they were severely damaged more than plants in the third planting date due to their advance growth stage. In addition to that, the accumulated heat units from emergence to maturity in the third planting date were greater by 83 units (Table 38) which is rather unexpected, but may be due to the very short interval between the second and third planting dates at Mushaqar.

There was no significant difference between the two locations for grain yield and biological yield (Table 6), however, the average grain yield at both locations was economically acceptable, which indicate that both Maru and Mushaqar locations represent suitable sites for cumin cultivation. Moreover, our results concerning the accumulated heat units and yield indicated that cumin grown at both Maru and

Mushaqar at all planting dates accumulated adequate heat units, however, greater yield was obtained when more heat units was accumulated (Fig. 25).

Nitrogen fertilization increased grain yield and biological yield at both locations, however, the increase at Mushaqar was not significant. Application of 40 kg N ha-1 at Maru increased grain yield by 26.8% and 3.6%, and increased biological yield by 28% and 10% as compared to unfertilized plots and those received 20 kg N ha^{-1}, respectively (Table 3 and Table 4). The positive relationship between nitrogen fertilizer and both grain and biological yield was expected since nitrogen fertilization increased the most important characters contributed to yield. For example, the 40 kg N ha^{-1} increased number of branches per plant by 8.8%, increased plant height by 7.8% and increased number of umbels per plant by 9%, as compared to unfertilized plants (Table 3). Our results were in line with those of Randhawa *et al*. (1996) who reported that increasing applied N fertilizer from 0 kg N ha^{-1} to 60, 90 and 120 kg N ha^{-1} increased grain yield of dill seed from 546 to 866, 1078 and 1079 kg ha^{-1}, and they reported that this increase in grain yield was due to the favorable effect of N application on yield attributing characters like branching, number of umbels $plant^{-1}$ and plant height. Similar to our results were also recorded by Naqi Shah *et al*. (2004) in a study conducted on mustard plant at Tandojam, Pakistan, they reported that 150-75 kg ha^{-1} NP fertilizer combination resulted in the highest grain yield (1503 kg ha^{-1}) as compared to 933, 1260, 1325, 1401 and 1433 kg ha^{-1} for control, 50-15, 75-30, 100-45 and 125-60 kg NP ha^{-1}, respectively.

The increase in grain yield and biological yield with increasing N fertilizer levels was in quadratic fashion (Fig. 4 and Fig. 6), the high r^2 for both yield components at both locations indicates a close relationship between grain yield, biological yield and N fertilization (Hakan, 2003). Response of grain yield and biological yield of cumin to 20 kg N ha^{-1} indicates that it was adequate for the high grain and straw yield production within the results obtained in this experiment, and that its capacity to respond to applied N above 20 kg ha^{-1} was not efficient.

It is well known that as plants per unit area increase, more competition will be occurred between plants on the soil moisture and nutrients and as a result in a reduction in single plant yield. However, the yield per unit area might increase due to the increase in the number of plants. This was found to be true under this study, where the higher seeding rate gave greater grain yield and significantly greater biological yield (Table 3). Some times, however, an economic assessment should be curried out to find if the increase in yield could compensate for the extra cost of doubling the seed rates. Similar to our results are those of Bianco *et al*. (1994) on fennel, where increased plant density from 1.7 plant m^{-2} to 5 plants m^{-2} increased grain yield from 1025 to 1647 kg ha^{-1}, and those of Randhawa *et al*.(1996) on dill seed, where increasing row spacing from 30 to 60 cm decreased grain yield from 1214 to 863 kg ha^{-1}, and Donaldson *et al*. (2001) in a trial conducted at Washington, USA, where increased plant population of wheat from 65 plants m $^{-2}$ to 130 and 195 plants m-^{2} increased straw yield of wheat from 4.5 ton ha^{-1} to 5.0 and 5.25 ton ha^{-1} respectively. Dry matter accumulation takes place at a slower rate until the crop reaches full ground coverage and then increases at a much faster rate. Angadi *et al*. (2003) working on canola plant at semiarid region of Canada reported that the delay in attaining full ground coverage with lower population prevents canola plants from efficiently utilize the solar radiation and was related to a lower biomass.

5.2 Yield components

At Maru location, planting date has a substantial influence on all yield components. Planting early on December 1 gave greater number of branches, more seeds currying umbels, more seeds per umbrella and larger number of seeds per plant as compared to planting on later dates of December 29 or January 31. However, the behavior of 1000 seed weight to planting date was the opposite, where heavier seeds were produced under the late sowings as compared to early sowing (Table 10).

As we discussed earlier with grain yield and biological yield, early planting date provide the plant with an extended growth period from seedling emergence to maturity, which was around 131 days as compared to 104 and 83 days for the second and third planting dates (Table 38). Under such conditions the plant gave more branches and has a better chance to produce more flowers and to have more seed set, which was eventually reflected on the total number of seeds per plant produced. Plants in the first date gave 132 and 122 more seeds as compared to that produced by plants under second and third planting dates, respectively (Table 10). Number of branches has strong correlation with other traits, so increasing number of branches in early planting date resulted in producing more umbels plant^{-1} and consequently more seeds plant^{-1} produced, which was reflected in an r^2 values of 0.50 and 0.44 between number of branches and both number of umbels plant^{-1} and number of seeds plant^{-1}, respectively. Also number of seeds plant^{-1} was strongly correlated with number of umbels plant^{-1} and number of seeds umbrella^{-1} with r2 values of 0.81 and 0.40 between number of seeds plant^{-1} and the two traits, respectively. At Mushaqar location, only number of branches per plant was significantly affected by planting date, and it was opposite to the results of Maru, where delaying sowing from December 30 to January 17 increased number of branches per plant by about 6% (Table 11). Which was unexpected, but the minor effect of the around zero temperature occurred on the night of March 26 on plants sown later in January 17 as compared to those sown on December 30, and the short interval between the 2nd and 3rd planting dates may explain the increase in number of branches with delaying sowing at Mushaqar.

Nitrogen fertilizer has an effect on number of branches per plant and number of umbels per plant, where the high dose of 40 kg N ha^{-1} improved the two characters as compared to zero and 20 kg N ha^{-1}, however, the effect on the other yield components was not pronounced. The effect of 40 kg N ha^{-1} on increase number of branches per plant was more pronounced under the December 1 plantation, and the effect start to reduced with delay sowing (Table 12), in fact no effect was noticed in that planting date, which indicate that plants in the 1st planting date have a better chance and longer time to utilize the applied nitrogen more than those grown later on December 29 and January 31. Similar results were recorded by Safwat and Badran (2002) in a study conducted at Minia University, Egypt, where cumin plant gave 6.4 branches with 200 kg N ha^{-1} as compared to 4.8 branches without nitrogen fertilization. Also our results are in line with what had been reported by Randhawa *et al*. (1996) under the conditions of Punjab, India, where application of nitrogen fertilizer on dill seed plant at a rate of 90 kg ha^{-1} gave 37 umbels per plant as compared to 30 and 36 umbels for plants received zero and 60 kg N ha^{-1}, respectively. Moreover, they recorded that number of braches per plant was increased from 4.8 to 5.7 when the nitrogen fertilizer level increased from zero to 60 kg ha^{-1}.

Seeding rate has different influence on yield components, where lower seeding rate (15 kg ha^{-1}) gave more branches, umbels per plant and greater 1000 seed weight, but less number of seeds per umbrella as compared with the other rates. However, the highest seed rate (30 kg ha^{-1}) gave the highest number of seeds per umbrella. This seems to be logical since under this seed rate the lower umbels per plant was resulted (9.7) and therefore produced more seeds per umbrella (Table 11).

Our results indicate a significant reduction in 1000 seed weight with increasing plant density at Maru. Higher plant population will lead to moisture stress especially at the end of the growing season, which coincide with grain filling stage, thus affect seed weight. Our results disagree with those of Damato *et al.* (1994) in a study conducted at south Italy, where an increase in 1000 seed weight was recorded by increasing plant density of fennel. While Angadi *et al*. (2003) work on canola at Canada and Carr *et al*. (2003) working on wheat at North Dakota. USA, reported no effect of plant density on 1000 seed weight.

5.3 plant height

Plant height was significantly affected by planting date, N fertilization and seeding rate at both locations (Table 29). At Maru location, plants sown early on December 1 were the tallest; it was taller by 21.5% and 29.8% as compared to those sown later on December 29 and January 31, respectively. This was expected since early sowing provided longer vegetative growth period and more accumulated heat units which were suitable for plants to get taller. Similar results were recorded by Luayza *et al*. (1996) on coriander, where delay sowing from July to September decreased plant height from 68 to 53 cm. But Hakan (2003) reported an increase in height of rapeseed plant from 98 cm to 118 cm by delaying sowing from April 9 to May 18. Plant height increased significantly with N fertilization at both locations, and the greatest response was to the highest N fertilizer level indicates the high requirement to N fertilizer during vegetative growth period. This finding is in agreement with Safwat and Badran (2002) on cumin, where plants under 100 kg N ha^{-1} were 43.4 cm tall compared to 34.4 cm for unfertilized plants. But Nikolova *et al.* (1999) reported no effect of N fertilization on plant height of chamomile plant. Our results showed an increase in plant height with increasing seeding rate until 25 kg ha^{-1} at both locations. Higher plant density leads to higher interplant competition on light resources which resulted in taller plants. Results of the interaction between N fertilizer and seeding rate (Table 34) indicate that with higher plant density, higher dose of N fertilizer should be used. Similar results were recorded by Damato *et al*. (1994) on fennel plant, where increasing plant density from 1.7 plant m^{-2} to 5 plants m^{-2} increased plant height from 89 cm to 111 cm, but Randhawa *et al*. (1996) reported no effect of plant density on plant height of dill seed. At Maru, plant height was strongly correlated with all yield components except with 1000 seed weight, which is reflected in an r^2 values ranged from 0.19 for number of branches $plant^{-1}$ to 0.34 for number of seeds $plant^{-1}$ (Table 39). So it is logical to observe significant, positive relationship between plant height and both grain yield and biological yield with an r^2 values of 0.28 and 0.31 for both traits, respectively, which indicated the importance of plant height trait in cumin yield, in addition to the importance of this trait in facilitating mechanical harvesting of the crop. The negative correlation between plant height and 1000 seed weight is expected since taller plants tend to have more branches, umbels, seeds $umbrella^{-1}$, and consequently have more seeds $plant^{-1}$.

5.4 oil content

Essential oil% (2.07%-2.40%) was close to the range recorded by Kizil *et al.* (2003), when they determined essential oil% of eight cumin lines to range from 1.87% to 2.37%. The total oil% ranged from 10.37% to 12.02% and oil yield (kg ha^{-1}) ranged from 71 to 92 kg ha^{-1} (Table 29). The negative correlation between oil% and 1000 seed weight with an r^2 value of 0.11 indicated that heavier grains contain less oil%.

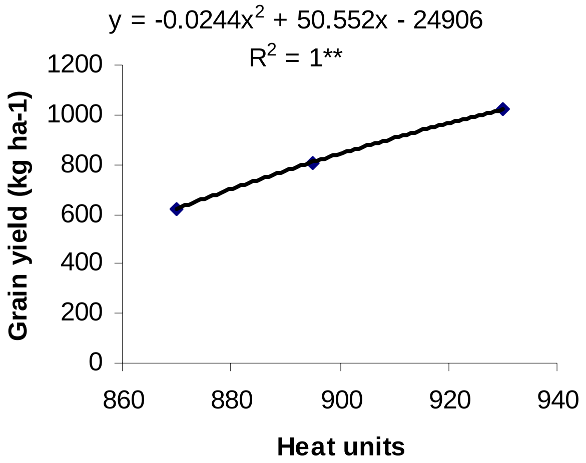

Figure 25: relationship between the accumulated heat units and grain yield for plants grown at Maru. ** = significant at 1%.

6. Conclusions and Recommendations

6.1 Conclusions

1. At Maru, early sowing on December 1 resulted in higher grain yield, biological yield, greater number of branches per plant, umbels per plant, seeds per umbrella and total seeds per plant, and in taller plants, but the weight of 1000 seed was lower as compared to later sowing on December 29 and January 31. While at Mushaqar, plants sown on December 29 were taller but with lower number of branches as compared to those sown on January 17.
2. At Maru, nitrogen fertilization significantly increased grain yield and biological yield, but there was no significant difference between plants under 20 and 40 kg N ha^{-1}. While at Mushaqar nitrogen fertilization had no significant effect on grain yield and biological yield.
3. Increasing plant density increased cumin yield at both locations, however, the optimum seeding rate at Maru was 30 kg ha^{-1}, while at Mushaqar it was 25 kg ha^{-1}.
4. Cumin plants sown on December 2 at Mushaqar had been damaged by the low temperature (2°C) at preflowering growth stage.

6.2. Recommendations

1. Cumin plant is sensitive to frost during the late vegetative growth stage, so it is important to avoid planting cumin at areas known to be exposed to frost especially with early sowings. However, a long term strategy should focus on the development of new cumin varieties which can tolerate frost and produce higher yield.

2. Cumin plant is not weed competitive especially at early growth stages, therefore, there is a need to investigate the appropriate weed control strategy for cumin.

3. There is a need to evaluate higher plant densities than 30 kg ha^{-1} with different row spacing to find out the optimum distribution of plants per unit area.

4. It is recommended to investigate the response of cumin to later planting dates after January, to find out the latest date for planting cumin under rainfed conditions of Jordan which can produce economical yield, taking into consideration its sensitivity to low temperature.

5. There is a need to study the nutrient requirement for cumin under rainfed conditions of Jordan.

6. It is recommended to maintain some of the seeds used in this study in the gene bank for further future studies.

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APPENDICES

Appendix A: analysis of variance for yield and yield components of cumin grown at Maru and Mushaqar during the growing season of 2004/2005.

A-1: Analysis of variance for grain yield of cumin grown at Maru.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	109074	54537	0.62	
PD	2	2878185	1439093	16.25	0.012
Error 1	4	354253	88563		
F	2	729425	364712	6.18	0.014
PD*F	4	791408	197852	3.35	0.046
Error 2	12	708506	59042		
SR	3	247532	82511	1.82	0.155
PD*SR	6	287448	47908	1.06	0.401
F*SR	6	179207	29868	0.66	0.683
PD*F*SR	12	382834	31903	0.70	0.742
Error 3	54	2450758	45384		
Total	107	9118629			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 26.1%.

A-2: Analysis of variance for biological yield of cumin grown at Maru.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	672358	336179	0.96	
PD	2	14395499	7197749	20.63	0.008
Error 1	4	1395422	348856		
F	2	3327640	1663820	7.37	0.008
PD*F	4	3304255	826064	3.66	0.036
Error 2	12	2708993	225749		
SR	3	1747384	582461	3.52	0.021
PD*SR	6	1125966	187661	1.13	0.355
F*SR	6	708804	118134	0.71	0.640
PD*F*SR	12	1506753	125563	0.76	0.688
Error 3	54	8934659	165457		
Total	107	39827733			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 23.5%.

A-3: Analysis of variance for harvest index of cumin grown at Maru.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	294.74	147.37	2.25	
PD	2	80.54	40.27	0.61	0.585
Error 1	4	262.18	65.54		
F	2	102.44	51.22	1.04	0.382
PD*F	4	274.57	68.64	1.40	0.292
Error 2	12	588.53	49.04		
SR	3	290.50	96.83	2.69	0.056
PD*SR	6	224.93	37.49	1.04	0.410
F*SR	6	162.42	27.07	0.75	0.611
PD*F*SR	12	888.38	74.03	1.05	0.037
Error 3	54	1946.46	36.05		
Total	107	5115.68			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation =12.7%.

A- 4: Analysis of variance for number of branches per plant of cumin grown at Maru.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	0.07042	0.03521	1.14	
PD	2	8.34347	4.17174	135.00	0.000
Error 1	4	0.12361	0.03090		
F	2	0.87722	0.43861	10.88	0.002
PD*F	4	0.60056	0.15014	3.72	0.034
Error 2	12	0.48389	0.04032		
SR	3	5.29414	1.76471	62.68	0.000
PD*SR	6	1.18634	0.19772	7.02	0.000
F*SR	6	0.76537	0.12756	4.53	0.000
PD*F*SR	12	1.98685	0.16557	5.88	0.000
Error 3	54	1.52042	0.02816		
Total	107	21.25229			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 6.5%.

A- 5: Analysis of variance for number of umbels per plant of cumin grown at Maru.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	97.7235	48.8618	90.30	
PD	2	401.4217	200.7109	370.91	0.000
Error 1	4	2.1645	0.5411		
F	2	15.2659	7.6329	7.02	0.010
PD*F	4	31.1022	7.7755	7.15	0.003
Error 2	12	13.0419	1.0868		
SR	3	45.0949	15.0316	17.65	0.000
PD*SR	6	48.8677	8.1446	9.57	0.000
F*SR	6	4.0258	0.6710	0.79	0.583
PD*F*SR	12	77.8278	6.4857	7.62	0.000
Error 3	54	45.9800	0.8515		
Total	107	782.5160			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 8.7%.

A- 6: Analysis of variance for number of seeds per umbrella of cumin grown at Maru.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	243.908	121.954	22.09	
PD	2	515.477	257.738	46.69	0.002
Error 1	4	22.079	5.520		
F	2	0.714	0.357	0.24	0.792
PD*F	4	75.889	18.972	12.61	0.000
Error 2	12	18.054	1.505		
SR	3	51.175	17.058	7.27	0.000
PD*SR	6	95.338	15.890	6.78	0.000
F*SR	6	28.160	4.693	2.00	0.081
PD*F*SR	12	107.149	8.929	3.81	0.000
Error 3	54	126.635	2.345		
Total	107	1284.578			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 6.3%.

A- 7: Analysis of variance for number of seeds per plant of cumin grown at Maru.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	170862	85431	19.86	
PD	2	386748	193374	44.96	0.002
Error 1	4	17204	4301		
F	2	6457	3229	2.19	0.155
PD*F	4	35876	8969	6.08	0.007
Error 2	12	17707	1476		
SR	3	25396	8465	7.30	0.000
PD*SR	6	40148	6691	5.77	0.000
F*SR	6	3010	502	0.43	0.854
PD*F*SR	12	44796	3933	3.22	0.002
Error 3	54	62586	1159		
Total	107	810790			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 13.1%.

A- 8: Analysis of variance for weight of 1000 seeds of cumin grown at Maru.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	0.04042	0.02021	1.19	
PD	2	5.34181	2.67090	157.63	0.000
Error 1	4	0.06778	0.01694		
F	2	0.06722	0.03361	2.17	0.157
PD*F	4	0.32472	0.08118	5.24	0.011
Error 2	12	0.18597	0.01550		
SR	3	0.22639	0.07546	4.86	0.005
PD*SR	6	0.04986	0.00831	0.53	0.779
F*SR	6	0.15500	0.02583	1.66	0.148
PD*F*SR	12	0.22583	0.01882	1.21	0.300
Error 3	54	0.83917	0.01554		
Total	107	7.52417			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 4.0%.

A- 9: Analysis of variance for plant height of cumin grown at Maru.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	32.7585	16.3793	1.99	
PD	2	454.4180	227.2090	27.63	0.005
Error 1	4	32.8904	8.2226		
F	2	59.1341	29.5670	9.65	0.003
PD*F	4	57.4881	14.3720	4.69	0.016
Error 2	12	36.7811	3.0651		
SR	3	16.6922	5.5641	7.51	0.000
PD*SR	6	13.9650	2.3275	3.14	0.010
F*SR	6	11.7267	1.9544	2.64	0.026
PD*F*SR	12	18.7844	1.5654	2.11	0.031
Error 3	54	39.9967	0.7407		
Total	107	774.6352			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 4.8%.

A-10: Analysis of variance for oil content of cumin grown at Maru.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	1	70.014	70.014	12.78	
PD	2	33.114	16.557	3.02	0.249
Error 1	2	10.954	5.477		
F	2	1.621	0.811	0.48	0.642
PD*F	4	2.429	0.607	0.36	0.831
Error 2	6	10.197	1.699		
SR	3	9.113	3.038	2.11	0.123
PD*SR	6	4.406	0.734	0.51	0.796
F*SR	6	7.992	1.332	0.92	0.494
PD*F*SR	12	19.104	1.592	1.10	0.396
Error 3	27	38.935	1.442		
Total	71	207.879			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 10.7%.

A-11: Analysis of variance for grain yield of cumin grown at Mushaqar.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	540734.	270367.	1.25	
PD	1	8788.	8788	0.04	0.859
Error 1	2	431574.	215787.		
F	2	28423.	14212.	0.06	0.940
PD*F	2	275066.	137533.	0.60	0.572
Error 2	8	1837695.	229712.		
SR	3	123759.	41253.	0.98	0.411
PD*SR	3	82781.	27594.	0.66	0.583
F*SR	6	174687.	29115.	0.69	0.655
PD*F*SR	6	230731.	38455.	0.92	0.494
Error 3	36	1508523.	41903.		
Total	71	5242761.			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 32.7%.

A-12: Analysis of variance for biological yield of cumin grown at Mushaqar.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	1965952.	982976	1.47	
PD	1	134649.	134649.	0.20	0.697
Error 1	2	1336619.	668310.		
F	2	208204.	104102.	0.10	0.910
PD*F	2	1147311.	573656.	0.53	0.611
Error 2	8	8738837.	1092355.		
SR	3	563497.	187832.	1.25	0.307
PD*SR	3	123702.	41234.	0.27	0.844
F*SR	6	387067.	64511.	0.43	0.855
PD*F*SR	6	856821.	142804.	0.95	0.474
Error 3	36	5425189.	150700		
Total	71	20887849.			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 27.83%.

A-13: Analysis of variance for harvest index of cumin grown at Mushaqar.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	58.01	29.01	0.71	
PD	1	0.06	0.06	0.00	0.973
Error 1	2	82.00	41.00		
F	2	68.13	34.06	0.73	0.509
PD*F	2	81.39	40.70	0.88	0.452
Error 2	8	370.93	46.37		
SR	3	4.49	1.50	0.03	0.993
PD*SR	3	275.04	91.68	1.73	0.178
F*SR	6	199.59	33.26	0.63	0.706
PD*F*SR	6	477.53	79.59	1.50	0.205
Error 3	36	1904.46	52.90		
Total	71	3521.62			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 16.3%.

A-14: Analysis of variance for number of branches per plant of cumin grown at Mushaqar.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	0.19750	0.09875	19.22	
PD	1	0.34722	0.34722	67.57	0.014
Error 1	2	0.01028	0.00514		0.005
F	2	1.67250	0.83625	10.78	0.005
PD*F	2	0.18694	0.09347	1.21	0.349
Error 2	8	0.62056	0.07757		
SR	3	2.38944	0.79648	22.08	0.000
PD*SR	3	0.10722	0.03574	0.99	0.408
F*SR	6	0.35639	0.05940	1.65	0.163
PD*F*SR	6	0.08861	0.01477	0.41	0.868
Error 3	36	1.29833	0.03606		
Total	71	7.27500			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 8.0%.

A-15: Analysis of variance for number of umbels per plant of cumin grown at Mushaqar.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	12.896	6.448	1.42	
PD	1	2.311	2.311	0.51	0.550
Error 1	2	9.106	4.553		
F	2	23.516	11.758	1.55	0.270
PD*F	2	7.006	3.503	0.46	0.646
Error 2	8	60.802	7.600		
SR	3	25.967	8.656	1.53	0.223
PD*SR	3	5.653	1.884	0.33	0.801
F*SR	6	57.321	9.553	1.69	0.152
PD*F*SR	6	50.215	8.369	1.48	0.212
Error 3	36	203.457	5.652		
Total	71	458.249			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 19.8%.

A-16: Analysis of variance for number of seeds per umbrella of cumin grown at Mushaqar.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	3.566	1.783	0.09	
PD	1	81.622	81.622	4.28	0.174
Error 1	2	38.141	19.070		
F	2	0.232	0.116	0.02	0.981
PD*F	2	2.794	1.397	0.22	0.805
Error 2	8	50.242	6.280		
SR	3	3.967	1.322	0.32	0.808
PD*SR	3	34.303	11.434	2.81	0.053
F*SR	6	107.907	17.985	4.41	0.002
PD*F*SR	6	26.285	4.381	1.08	0.395
Error 3	36	143.666	4.074		
Total	71	495.725			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 17.8%.

A-17: Analysis of variance for number of seeds per plant of cumin grown at Mushaqar.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	568	284	0.05	
PD	1	6572	6572	1.09	0.406
Error 1	2	12058	6029		
F	2	2538	1269	0.64	0.552
PD*F	2	1915	957	0.48	0.633
Error 2	8	15820	1978		
SR	3	5232	1744	1.56	0.216
PD*SR	3	10105	3368	3.01	0.043
F*SR	6	38247	6375	5.70	0.000
PD*F*SR	6	16532	2755	2.46	0.042
Error 3	36	40282	1119		
Total	71	149869			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 24.5%.

A-18: Analysis of variance for the weight of 1000 seeds of cumin grown at Mushaqar.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	0.08764	0.04382	0.44	
PD	1	0.05390	0.05390	0.54	0.54
Error 1	2	0.20114	0.10057		
F	2	0.07380	0.03690	2.11	0.183
PD*F	2	0.02230	0.01115	0.64	0.553
Error 2	8	0.13963	0.01745		
SR	3	0.03098	0.01033	0.55	0.650
PD*SR	3	0.06576	0.02192	1.17	0.334
F*SR	6	0.09963	0.01661	0.89	0.514
PD*F*SR	6	0.15569	0.02595	1.39	0.247
Error 3	36	0.67387	0.01872		
Total	71				

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 5.1%.

A-19: Analysis of variance for plant height of cumin grown at Mushaqar.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	0.3026	0.1513	0.57	
PD	1	126.1401	126.1401	472.96	0.002
Error 1	2	0.5334	0.2667		
F	2	8.3326	4.1663	21.48	0.000
PD*F	2	2.3063	1.1532	5.94	0.026
Error 2	8	1.5519	0.1940		
SR	3	14.1649	4.7216	25.43	0.000
PD*SR	3	6.0138	2.0046	10.79	0.000
F*SR	6	7.4458	1.2410	6.68	0.000
PD*F*SR	6	12.3815	2.0636	11.11	0.000
Error 3	36	6.6854	0.1857		
Total	71	185.8582			

R: replicate, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 2.57%.

A-20: Over location analysis of variance for grain yield grown at Maru and Mushaqar.

Source of variation	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	134778.875	67389.438	0.2620	
L	1	289623.361	289623.361	1.1259	0.3999
Error 1	2	514490.431	257245.215		
PD	1	246346.778	246346.778	2.2212	0.2104
L*PD	1	395641.000	395641.000	3.5672	0.1319
Error 2	4	443637.639	110909.410		
F	2	440001.542	220000.771	1.4640	0.2607
L*F	2	219344.597	109672.299	0.7298	
PD*F	2	100989.847	50494.924	0.3360	
L*PD*F	2	729938.625	364969.313	2.4287	0.1199
Error 3	16	2404381.556	150273.847		
SR	3	231143.917	77047.972	1.7122	0.1721
L*SR	3	102847.472	34282.491	0.7619	
PD*SR	3	190814.611	63604.870	1.4135	0.2459
L*PD*SR	3	160290.167	53430.056	1.1874	0.3207
F*SR	6	111517.458	18586.243	0.4130	
L*F*SR	6	194549.736	32424.956	0.7206	
PD*F*SR	6	171730.264	28621.711	0.6361	
L*PD*F*SR	6	244807.042	40801.174	0.9067	
E4	72	3239870.833	44998.206		
Total	143	10566745.750			

R: replicate, L: location, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 31.6%.

A-21: Over location analysis of variance for biological yield of cumin grown at Maru and Mushaqar.

Source of variance	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	475637.316	237818.658	0.2283	
L	1	417176.894	417176.894	0.4005	
Error 1	2	2083295.415	1041647.708		
PD	1	809506.258	809506.258	2.7826	0.1706
L*PD	1	1662228.331	1662228.331	5.7137	0.0751
Error 2	4	1163683.600	290920.900		
F	2	1508853.564	754426.782	1.1669	0.3365
L*F	2	433556.029	216778.014	0.3353	
PD*F	2	490535.749	245267.874	0.3794	
L*PD*F	2	2032145.283	1016072.642	1.5716	0.2381
Error 3	16	10344193.267	646512.079		
SR	3	1280129.469	426709.823	2.4062	0.0743
L*SR	3	392517.221	130839.074	0.7378	
PD*SR	3	1040217.888	346739.296	1.9552	0.1284
L*PD*SR	3	276960.920	92320.307	0.5206	
F*SR	6	429115.853	71519.309	0.4033	
L*F*SR	6	527160.283	87860.047	0.4954	
PD*F*SR	6	499641.947	83273.658	0.4696	
L*PD*F*SR	6	883617.192	147269.532	0.8304	
E4	72	12768306.153	177337.585		
Total	143	39518478.634			

R: replicate, L: location, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 29.3%.

A-22: Over location analysis of variance for harvest index of cumin grown at Maru and Mushaqar.

Source of variance	Degrees of freedom	Sum of square	Mean square	F value	Probability level
R	2	126.478	63.239	492.5042	0.0020
L	1	390.721	390.721	3042.9304	0.0003
Error 1	2	0.257	0.128		
PD	1	0.028	0.028	0.0005	
L*PD	1	0.034	0.034	0.0006	
Error 2	4	240.885	60.221		
F	2	17.915	8.958	0.2477	
L*F	2	234.313	117.156	3.2395	0.0659
PD*F	2	22.704	11.352	0.3139	
L*PD*F	2	186.003	93.001	2.5716	0.1075
Error 3	16	578.640	36.165		
SR	3	88.865	29.622	0.7021	
L*SR	3	83.385	27.795	0.6588	
PD*SR	3	201.241	67.080	1.5901	0.1992
L*PD*SR	3	206.345	68.782	1.6304	0.1899
F*SR	6	163.534	27.256	0.6461	
L*F*SR	6	245.515	40.919	0.9699	
PD*F*SR	6	328.874	54.812	1.2993	0.2686
L*PD*F*SR	6	754.989	125.831	2.9827	0.0117
E4	72	3037.474	42.187		
Total	143	6908.197			

R: replicate, L: location, PD: planting date, F: N fertilizer, SR: seeding rate.
Coefficient of Variation = 14.07%.

Appendix B: Climatic information on the two locations.

B-1: Maximum, minimum and average monthly temperature (°C) at Maru and Mushaqar for the last 10 years (94/95-2003/2004).

	Mushaqar			Maru		
Month	Maximum	Minimum	Average	Maximum	Minimum	Average
12	14.5	3.0	8.7	19.7	8.0	13.9
1	13.3	3.3	8.3	14.1	4.9	9.5
2	13.8	3.3	8.5	13.6	4.4	9.0
3	19.0	5.7	12.4	19.4	7.0	13.2
4	24.0	9.0	16.5	24.0	10.0	17.1
5	26.2	10.4	18.3	28.0	13.0	20.5

B-2: Maximum, minimum and average monthly temperature (°C) at Maru and Mushaqar during the growing season of 2004-2005.

	Maru			Mushaqar		
Month	Max.	Min.	Aver.	Max.	Min.	Aver.
12/2004	18.4	8.0	13.2	14.5	3.0	8.7
1/2005	14.1	4.1	9.2	16.5	2.6	9.6
2/2005	13.5	4.4	9.0	13.8	3.3	8.5
3/2005	19.4	6.5	13.0	18.4	5.5	12.0
4/2005	24.0	8.4	16.2	24.0	9.0	16.5
5/2005	27.0	10.9	19.0	26.2	10.4	18.3

B-3: Average monthly rainfall for the period 94/95 –2003/2004 at Maru and Mushaqar

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
Mushaqar	7.5	32.7	66.0	86.0	61.0	53.4	11.3	1.5
Maru	11.7	37.3	80.8	93.5	87.6	76.5	17.5	2.4

B-4: The amount of monthly rainfall (mm) in the two locations during the growing season of 2004/2005

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total
Mushaqar	2.5	164.8	34	121.6	89.1	49	1.5		462.5
Maru	13.5	115.5	29	66.4	159.8	17.4	11.6	15	428.2

B-5: Amounts of annual rainfall (mm) in the two locations during the period from 1994 to 2003

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Aver
Mushaqar	299	435	237	322	322	153	246	261	462	424	316
Maru	337	388	333	419	505	185	343	263	459	765	400

تأثير موعد الزراعة، معدل البذار والتسميد النيتروجيني على الغلة وبعض الصفات الأخرى لمحصول الكمون تحت ظروف الزراعة المطرية في الأردن

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اشراف
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ملخص

الكمون نبات عشبي حولي ينتمي إلى العائلة الخيمية، موطنه الأصلي حوض البحر المتوسط، و له عدة استخدامات غذائية وطبية.

المعلومات غير متوفرة حول موعد الزراعة المناسب، الاحتياجات من السماد النيتروجيني ومعدل البذار لنبات الكمون. لذا فقد تم تنفيذ هذا البحث لتحديد اثر موعد الزراعة، السماد النيتروجيني ومعدل البذار على إنتاجية الكمون تحت ظروف الزراعة المطرية في الأردن.

تم تنفيذ البحث خلال الموسم الزراعي 2005/2004 في محطتي المشقر و مرو التابعتين للمركز الوطني للبحوث الزراعية و نقل التكنولوجيا. تكونت المعاملات من ثلاثة مواعيد زراعة (بداية كانون الأول، نهاية كانون الأول و منتصف إلى نهاية كانون الثاني)، و ثلاثة مستويات من السماد النيتروجيني (دون تسميد، 20 كغم/هكتار و 40 كغم/هكتار) و أربعة معدلات بذار(15، 20، 25 و 30 كغم/هكتار)، تم توزيع المعاملات في التجربة بطريقة القطع المنشقة المنشقة باستعمال تصميم القطع العشوائية الكاملة بثلاثة مكررات، حيث احتلت مواعيد الزراعة القطع الرئيسية من التصميم، فيما احتلت مستويات السماد القطع الثانوية الأولى ومواعيد الزراعة القطع الثانوية الثانية.

دلت النتائج في محطة مرو على أن الزراعة المبكرة في 12/1 أدت إلى زيادة في إنتاج الحب بنسبة 26% و 64%, وزيادة في الإنتاج البيولوجي بنسبة 31% و 68% مقارنة مع الزراعة في 12/29 و 1/31 على التوالي. كما أدت الزراعة المبكرة إلى زيادة كل من ارتفاع النبات، عدد الأفرع الرئيسة للنبات، عدد المظلات للنبات، عدد البذور للمظلة و عدد البذور للنبات. فيما أدت إلى نقص في وزن الألف بذرة. تبكير الزراعة أدت إلى زيادة في دورة حياة

النبات, حيث استمرت دورة حياة النباتات المزروعة في موعد الزراعة الأول مـدة 158 يـوم مقارنة مع 134 يوم و 111 يوم لكل من نباتات الموعد الثاني والثالث علـى التـوالي. عـدد الوحدات الحرارية المجمعة لنباتات الموعد الأول كان 1155 وحدة مقارنة مـع 1025 و 988 وحدة لنباتات الموعدين الثاني و الثالث على التوالي.

في المشقر أدى تدني درجة الحرارة ليلة 2005/3/26 إلى ما حول الصفر المئوي إلـى موت النباتات المزروعة في 12/2, النباتات المزروعة في 12/30 كانت أطول مـن النباتـات المزروعة في 1/17 و لكن بعدد أفرع أقل. دورة حياة النباتات المزروعة في 12/30 استمرت 143 يوم جمعت خلالها 950 وحدة حرارية, مقارنة مع 132 يـوم و 1032 وحـدة حراريـة للنباتات المزروعة في 1/17.

إضافة السماد النيتروجيني في محطة مرو بمعدل 20 و 40 كغم/هكتار أدت إلى زيـادة في إنتاج الحب بمقدار 22% و 27%، و زيادة في الإنتاج البيولـوجي بمقـدار 17% و 28% مقارنة بالمعاملات التي لم تسمد، كما أدت إضافة السماد النيتروجيني إلى زيادة كل من ارتفـاع النبات، عدد الأفرع الرئيسة للنبات وعدد المظلات للنبات، لكنه لم يؤثر معنويا على كـل مـن مؤشر الحصاد، محتوى الزيت، عدد البذور للنبات و وزن الألف بذرة. أما فـي المـشقر فـأن إضافة السماد أدت إلى زيادة في ارتفاع النبات وعدد الأفرع الرئيسة فقط.

دلت النتائج في محطة مرو على أن الكمون المزروع بمعدل بذار 30 كغـم/هكتـار كـان الأعلى في إنتاج الحب والإنتاج البيولوجي، بينما أعطى معدل البذار 15 كغم/هكتار عددا أكبـر من الأفرع الرئيسة للنبات، عددا أكبر من المظلات للنبات وعددا اكبر من البذور للنبات. لكـن وزن الألف بذرة كان الأعلى عند معدل البذار 20 كغم/هكتار. أما في المشقر فأن الـذي تـأثر بمعدل البذار فهو طول النبات وعدد الأفرع للنبات فقط, فقد سجلت أطول النباتات عنـد معـدل البذار 25 كغم/هكتار, أما معدل البذار 15 كغم/هكتار فقد أعطى أكبر عدد من الأفرع للنبات.