RESPONSE OF TEN LENTIL GENOTYPES TO SIMULATED DROUGHT CONDITIONS

BY

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TO MY MOTHER, BROTHERS

AND SISTERS

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ABSTRACT

Ten lentil genotypes were tested in Ramtha station under different water levels by using sprinkler line source, during the 1984/85 and 1985/86 growing seasons. Five different levels of water were used. The water was supplied only during long periods of no rain. The genotypes were replicated four times in a Ranomized Complete Block Design.

The same genotypes were tested in Ramtha, Maru and Jubeiha locations for their yield stability under different environments, using the same design. Two planting dates were used; the first was at the beginning of growing season and the second was 6 to 8 weeks later.

Moreover, a laboratory test using D-mannitol to simulate drought conditions was conducted for measuring drought tolerance at the seedling stage.

The results indicated that all the 10 genotypes were significantly affected by moisture stress level, and increasing soil moisture increased grain yield, the number of primary and secondary branches, plant height, the number of pods per plant, the number of nodules per plant.

Among the 10 genotypes tested, 76 TA 66088, Winter lik-51 and UJL 405 showed the least grain yield reduction percentages in response to increased moisture stress level; from W4 to W0; indicating the ability of these genotypes to resist drought over the other tested genotypes.

Grain yield was positively and significantly correlated with the amount of water applied plus rainfall for all the genotypes tested; coefficient of determination (r^2) ranged from 0.79 to 0.92 for both growing seasons.

However, Winter lik-51, UJL 289 and 78 S-26013 had the greatest yield response to applied water (b= 7.964, 7.532 and 7.367, respectively) during the 1984/85 season; whereas genotypes UJL 405, ILL 4401 and Winter lik-51 had the greatest yield response (b= 4.758, 4.492 and 4.449, respectively) during the 1985/86 season.

When comparing the genotypes ILL 4400 and UJL 176 in respect of water use, the data strongly suggested that ILL 4400 had higher water use than UJL 176 under all the water levels during both seasons. However the data also suggested that water use efficiency was higher for biological yield in ILL 4400 than UJL 176; whereas UJL 176 had higher water use efficiency for grain yield in both seasons.

The results also indicated that the genotype UJL 405 was widely adapted, having the highest mean grain yield (567 kg ha^{-1}), and a regression coefficient relatively near to unity ($b > 1$) which indicated that it possessed average stability. The variance due to deviation was also small. This genotype was followed by UJL 176 and UJL 289. However, UJL 405, 76 TA 66088 and Winter lik-51 possess some yield components stable in response to environments, such as number of pods per plant and number of seeds per pod, and therefore, they should be involved in a breeding

1. INTRODUCTION

Lentils (Lens culinaris Medic), one of the oldest cultivated crops, are known to be one of the most nutritious food legumes.

Lentils have the ability to fix the atmospheric nitrogen through their symbiotic relationship with Rhizobium bacteria, thus adding nitrogen to the soil and consequently decreasing the requirements of nitrogen fertilizers, this makes them essential in the crop rotation (Saxena,1981). The straw yield is also an important product as livestock feed.

The lentil seed is an important source of protein in the daily food consumption of people in many countries of the world, particularly in the Middle East and West Asia. Protein content of lentils is around 24 % (Tannous et al., 1978).

In Jordan lentil is the most important legume crop. It occupies large areas under rainfed agriculture when compared to chickpea and faba-bean. It is the second field crop after wheat.

Lentil cultivated area decreased from 21554 hectares in 1974 to 4857 hectares in 1984 (Anon., 1974-1984).The progressive reduction in cultivated area of lentils in Jordan is mainly due to low return from growing this crop; this is because of the low yield and high labor cost needed for harvesting the crop which is done manually.

The yield of lentils in Jordan is low, it averaged 695 kg ha^{-1} for the period 1974 to 1984 (Anon., 1974-1984). This low yield is attributed to several factors one of which is the low and unevenly distributed rainfall, and the poor cultural practices.

Testing for drought tolerance is of great practical importance. However, the fluctuations that occur from year to year and from location to location in drought incidence makes field testing difficult (Salim et al., 1966).

One of the major problems facing rainfed agriculture in Jordan is the drought which is characterized by the moisture stress prevailing at the end of the growing season. Moisture stress sometimes is also a problem at the start of the growing season during seed germination. Therefore, drought is considered as a major problem facing the improvement in lentil yield and other crops as well. Selecting lentil genotypes which resist or tolerate drought is an important goal of breeders and agronomists in the region. This could result in the development of varieties which show more stability under variable environmental conditions specially low soil moisture.

The main objectives of this work are:

(1) To evaluate the response in yield of 10 lentil genotypes to drought.

(2) To test and select stable genotypes that interact with the environment in which they are to be grown, in order to aid plant breeders in selection of superior genotypes and,

(3) To evaluate D-mannitol as simulated moisture stress agent for lentil seed germination and to correlate germination test with field test.

2. REVIEW OF LITERATURE

2.1. RESPONSE OF LENTILS TO WATER STRESS:

2.1.1. Effect of Water Stress on Lentil Yield:

The effect of water stress on lentil yield has been the subject of investigation by many researchers for a long time. In the following paragraphs, some of the previous work related to this subject is cited.

A study was conducted by scientists from the International Center for Agricultural Research in the Dry Areas (ICARDA) at Tel-Hadya, Syria, to develop a reliable method of screening for water stress tolerance, in this study 12 genotypes of lentil were tested under three moisture regimes; adequate moisture supply assured by supplementary irrigation (345 mm of rain + 70 mm of irrigation, M_1), rainfed conditions (345 mm of total moisture, M_2), and 300 mm of total moisture supply obtained by excluding additional rain through the use of plastic sheet (M_3). The results indicated that variations in moisture supply significantly affected the performance of crop. Genotypic differences in response to the moisture supply were not statistically significant, specifically, genotypes ILL 101, 470, 4401 (from Syria), 793 (from Egypt) and 4354 (from Jordan) appeared to show less sensitivity to reduced moisture supply than the rest of the genotypes (ICARDA, 1981). In another study performed by ICARDA scientists, a yield trial was conducted to study the response of 12 lentil genotypes to three moisture conditions. The first trial was at Tel-Hadya with seasonal rainfall of 322 mm; the second was at Breda with seasonal rainfall of 260 mm; and the third was at Tel-Hadya but with supplementary irrigation of 150 mm added in three irrigations between early April and early May. The results showed that the yield was closely related to available moisture; greater biological yield was obtained under high moisture condition at Tel-Hadya location. The results also showed that the yield of all genotypes was reduced at the driest location at Breda. The reduction in yield, however, was not the same for the different genotypes; the least reduction recorded for ILL 8, 9, 16, 4354 (from Jordan) and ILL 1861 (from Sudan) (ICARDA, 1983).

Boyer and McPherson (1975) indicated that the ability of cereal crop varieties to endure or recover from the moisture stress will depend on the intensity and duration of stress, and on the stage of crop growth because physiologically all growth stages are not equally sensitive to moisture stress. An extensive study was conducted to determine the critical stage of crop growth to water deficit stress. A study was conducted in India, by Panwar and Paliwal (1975) on lentil showed that one irrigation at early pod filling stage was effective and resulted in 100 % yield increase over the unirrigated control. Similarly, Mehrotra <u>et al.</u> (1977), in India, found that lentils gave significantly higher yield when one supplementary irrigation (88.6 mm) was applied at pod formation over that obtained when the irrigation (78.7 mm) was applied at preflowering stage. The total rainfall received during crop season was 101.5 mm. On the other hand, Ojha et al. (1977) reported that the best yield response was obtained when irrigation was applied either at pre or post-flowering stage. The results of the study showed that lentil genotypes were significantly different where L9-12 out-yielded the others (T36, TT3 and local).

In another study, Singh et al. (1979), in India, found that two supplementary irrigations, one at 45 days after sowing and the other at early pod stage (amounts of applied water were not reported) resulted in higher yields when compared to that obtained when the crop was irrigated at 45 days and at 45 and 75 days after sowing or received no irrigation. Total rainfall received was 22.1 mm, however, all the treatments were supplied with one irrigation before sowing.

Saxena and Wassimi (1980) studied the effect of soil moisture content on the grain yield of 8 lentil genotypes, at Tel-Hadya, Syria, under 2 moisture levels. The first level was 240 mm as rain over the whole season, and the second level was created by applying two supplementary irrigations after termination of the rains (amounts of applied water were not reported). They found that grain yield was increased with increasing moisture supply. On the other hand, Hamoudi et al. (1983), at NewDelhi, India, investigating the effect of soil moisture regimes during vegetative (Pre-flowering) and reproductive (Post-flowering) growth stages on yield of lentil variety "Pusa 4". They found that irrigation supply at 0.5 atm tension (amounts of applied water were not reported) during pre - and post - flowering growth stages resulted in significantly higher grain yield over other treatments (the soil moisture tension was maintained at 1.0 and 1.5 atm during pre - and post - flowering phases and control).

In a recent study, Nema et al. (1984), in India, indicated the importance of timing of the supplementary irrigation on lentil yield; they found that one irrigation applied at the pre - flowering stage increased lentil seed yield by 10.0 % and 24.0 % over the application of one irrigation at post - flowering stage and pod filling stage, respectively. However, 50.6 % increase in yield was obtained by applying single irrigation at preflowering stage when compare it with control. Similarly, Singh et al. (1983), also in India, conducted an experiment on lentil with 3 levels of irrigation; no irrigation, one irrigation at seedling stage (60 mm of water added) and two irrigations at seedling and flowering stages (120 mm of water added, 60 mm in each irrigation). They found that one irrigation treatment increased the grain yield by 13.8 % and the two-irrigation treatment by 24.5 % over the control.

More recently, Saraf and Baitha (1985) found that lentil grain yield was increased from 952 kg ha^{-1} with no irrigation to 1557 kg ha^{-1} when two supplementary irrigations were applied (irrigation amounts were not reported).

It can be concluded from the previous literature that lentil yield is seriously affected by the amount of water supplied and the time of application. In general, lentil grain yield increased as the amount of applied water increased. Water application at the pre- and post - flowering stages effectively increased lentil yields; these two stages were found to be the most critical stages in plant growth to water deficit stress as reported by many researchers.

2.1.2. Effect of Soil Moisture on Some Agronomic Traits:

Irrigation increases the moisture in the soil profile and makes it more available to the plant, thereby enhancing almost all physio-chemical processes that ultimately contribute towards grain production. This well exemplified by improvement in many characters such as plant height, branches number and pods number per plant (Singh et al., 1983). Similarly, Verma and Kalra (1981 b) found that plant height, number of branches, dry matter production yield, and yield contributing characters such as number of pods per plant improved with the increase in number of irrigation, being highest under two supplementary irrigations (one irrigation at 60 days and the other at 105 days after sowing). On the average, under these two irrigations, the researchers obtained 12.6, 8.6 and 25.8% more pods per plant as compared with one irrigation applied at 105 days or at 60 days after sowing and no irrigation, respectively. On the other hand, in field trials at Assuit, Egypt, during 1977-1979 seasons, lentil cultivar Giza 9 was irrigated every 20, 40 or 60 days (irrigation amounts were not reported). It was found that number of branches per plant, number of pods per plant, and 100-seed weight were the highest with irrigation frequency of 40 days (Abdel-Rahman et al., 1980). Similar results were found by Nema et al. (1984), in India, that supplementary irrigation

(irrigation amounts were not reported) increased plant height, 100-seed weight, and number of pods per plant. The 100-seed weight, however, was significantly higher when irrigation was given at pod filling stage than at pre-flowering and post-flowering stages. Similar observations were reported in India (Mehrotra et al., 1977).

2.1.3. Effect of Soil Moisture on Nodulation:

The nitrogen fixation process is sensitive to water stress as indicated by many researchers. Limited work was conducted on lentil concerning this subject, however, several studies were conducted on some other legume crops.

Saraf and Baitha (1982), working with lentil in India, found that the average number of nodules increased by maintaining the soil moisture at 2 atm. Sprent (1972) working with fababeans (*Vicia faba* L.) and soybeans (*Glycine max* L.) suggested that water stress would reduce N-fixation by direct effect on the nodules but this might be aggravated by the inability of stressed leaves to supply photosynthate to nodules.

Matheny and Hunt (1983), in the south eastern coastal plain of USA, indicated that nodulation of soybeans was significantly affected by available moisture, using two water regimes (well watered and stressed). They found that water stressed soybean had significantly fewer nodules than the irrigated plants. Similarly, Zablotowicz et al. (1981), in California, USA, conducted a study to investigate the development of nodulation and N-fixation of cowpeas (*Vigna unguiculata* L.) as influenced by stage of growth and drought, using two water regimes (well-watered and droughted). The results indicated that maximum nodulation was obtained at the flowering stage under the well watered plots.

2.1.4. Evapotranspiration and Water Use Efficiency:

The effect of available soil moisture in the root zone during different stages of plant is an important factor in determining water use by any crop. Water use efficiency (WUE) was defined by Shouse *et al.* (1981) as the ratio of the seed yield per hectare to the amount of measured crop Evapotranspiration (ET).

Singh *et al.* (1983) indicated that the consumptive use of lentils varied with irrigation level. The average seasonal consumptive use of water ranged from 168.5 mm with no irrigation (35.4 mm of rain) to 261.9 mm with 2 supplementary irrigations (35.4 mm of rain + 120 mm of irrigation). Similarly, Hamoudi *et al.* (1983), in India, found that the consumptive water use (mm) for lentil grown under different soil moisture conditions during pre-and post-flowering stages, varied from 451.9 mm in well watered soil to 224.9 mm from the soil which has maximum moisture stress. On the other hand, Saraf and Baitha (1985), found that the total water use for lentil grown under different moisture regimes, ranged from 115 mm with no irrigation to 228 mm from the soil which received the highest amount of irrigation (irrigation amounts were not reported).

Earliness combined with higher growth rates appears to be the key factor in improving the water use efficiency. In field trials conducted by ICARDA scientists, at Tel-Hadya and Breda, Syria, to search for moisture stress-avoiding genotypes; they found that lentil genotypes maturing latest (ILL 793 and 4340) had the highest consumptive use of water. The genotype ILL 9, a relatively earlier maturing genotype, had the lowest water use and the highest water use efficiency (ICARDA, 1983).

Mehrotra et al. (1977), in India, indicated that maximum water use efficiency was obtained by lentils where only one irrigation (water amount was not reported) was supplied at pod formation growth stage.

In other crops, extensive work was conducted to study water use and water use-efficiency. Singh et al. (1978) working with peas (*Pisum sativum* L.), in India, indicated that production per unit area per unit volume of water used can be raised by irrigating at a stage which responds most to water application. However, the highest value for water use efficiency was recorded under one pre-flowering supplementary irrigation treatment followed by no post-sowing irrigation treatment and lowest in plots which received three irrigations (water amounts were not reported).

Miller and Burke (1983), in USA, conducted a study to evaluate the response of dry beans (*Phaseolus vulgaris* L.) to variable amounts of water using sprinkler line source. They found that total water used, including that depleted from the soil, ranged from about 220 mm at low irrigation rates to 270 mm with the highest rate, with no increase in yield, however, amounts of applied water, ranged from 172 mm at low irrigation rate to 302 mm with the highest rate. Similarly, Hang and Evans (1985), in USA, conducted a study to compare the effect of regularly scheduled adequate and deficit sprinkler irrigation on sunflower (Helianthus annuus L.) water use efficiency. They found that increased irrigation water resulted in increased yield, however, water use efficiency decreased with increasing irrigation rates. Similar results was observed by Shouse et al. (1981), working with cowpeas.

2.2 STABILITY OF YIELD AND YIELD COMPONENTS IN LENTIL:

A phenotype is the result of an interplay between genotype and its surrounding environment. A genotype does not exhibit the same phenotypic characteristics under all environments, and different genotypes respond differently to a specified environment. Accordingly the regulatory mechanisms afford variability in interaction of genotype X environment and enables the organism to survive and be productive under a range of environmental conditions (Ahmad and Pandey, 1983).

Genotype - environment interactions are of major importance to the plant breeder for varietal improvement. When varieties are compared over a series of environments the relative ranking usually differs, thus causes difficulty in demonstrating the significant superiority of any variety. This interaction is usually present whether the varieties are pure lines, or any other material with which the breeder may be working (Eberhart and Russell, 1966).

Finlay and Wilkinson (1963) suggested the linear regression of genotype X environment interactions could be used as a measure of stability; they proposed that an ideal, widely adapted cultivar would have maximum yield potential in the most favorable environment with maximum phenotypic stability (small regression coefficient, b).

Eberhart and Russell (1966) emphasised that both linear (b) and non-linear (sd^2) components of genotype X environment interaction should be considered in judging the phenotypic stability of a genotype. They described an ideal cultivar as having a high mean yield, an average response to environments and a small sd^2 . However, Keim and Kronstad (1979) proposed that an ideal cultivar must have both the highest yield under the most severly stressed environment expected and strong response ($b > 1$) to more favorable environments. On the other hand, Joppa et al. (1971) indicated that specific cultivar instabilities would lead to high sd^2 values.

Information with regard to phenotypic stability in lentils is limited.

Ahmad and Pandey (1983), in India, tested 10 lentil genotypes for phenotypic stability using the method suggested by Eberhart and Russell (1966). Where the phenotypic stability of the genotypes was measured by three parameters; mean performance over environments, the linear regression and the deviations from regression function. They found that the genotype LL 116 was the highest yielding genotype, but it was not a stable genotype expressing large deviation from linearity. The genotypes

LL 30, LL 19, LL 1 and LL 56 gave higher seed yield than the population mean. These four genotypes combined mean performance with unit linear response and low deviations from linearity, proved to be the most stable and widely adapted. Similarly, Singh and Mehra (1976), in India, tested eleven lentil genotypes in 23 locations comprising all the lentil growing regions of India for their yield stability. The results indicated that the varieties and the variety by environment interaction were significant, showing thereby that the varieties in the set differed in their adaptability. They also found that the variety T-36 was widely adapted having the highest mean yield in the set, and a regression coefficient equal to unity which indicated that it possessed average stability. The variance due to deviations from linear regression was also small. However, the earliest maturing varieties (Pusa-1 and B 77) showed the lowest yielding with a regression coefficient less than unity; and with high deviations from linear regression. They speculate that non-linear interaction may be associated with early maturity.

Mehra and Pahuja (1979), also in India, conducted a study to test 18 lentil varieties grown at seven locations, for their yield stability. Their results showed a significant variety X environment for yield. They also found that none of the regression coefficients (b) were significantly different from unity which indicated the absence of the difference in varietal response to environmental stimuli. However, the heterogeneity between regression component was significant for pods per plant and 100 seed weight, which they considered as the most important primary yield components.

In contrary, Sagar and Lal (1980), in India, tested fifteen varieties of lentil for their phenotypic stability during 1973/74 to 1975/76 seasons, where the stability analysis was done according to Eberhart and Russell (1966). They found that the varieties were different under different environments as the GXE component of variance was highly significant. Differences in mean values of varieties in different years revealed that seasons were different. Excpetionally high yields were obtained under the favorable environment of 1975/76 whereas low yields were obtained during 1974/75 season when environmental conditions were not favorable. They also found that varieties Pant 406, Pant 538, LL 5, Pant 638 and Ps 43 appeared to be promising as they gave higher mean yield.

2.3 EFEECT OF SIMULATED MOISTURE STRESS ON LENTIL SEED GERMINATION:

Seed germination and vigor are pre-requisites for the success of stand establishment of crop plants. Under rainfed conditions of arid and semi-arid regions, low moisture often is a limiting factor during seed germination (Ashraf and Abu-Shakra, 1978). Large areas in the Middle Eastern countries are characterized by low and erratic rainfall during late fall and early winter. Lentil as well as other winter crops such as wheat are sown during this period and usually suffer from early moisture stress resulting in a poor stand establishment in the field.

Little is known about the effect of soil moisture stress on germination of lentil seeds. It was found in Spring wheat (Triticum aestivum L.) that genotypes had high germination percentages usually lead to successful stand establishments under drought or potential drought conditions (Kazemi et al., 1977).

So far, most studies of drought tolerance on germination have been done under field conditions; however, the control of moisture and other environmental factors is difficult to maintain in the field, thus laboratory studies seem to be of significant value (Helmerick and Pfeifer, 1954). Different osmotic agents have been used to induce moisture stress and simulate drought conditions during germination in different crops (Ashraf and Abu-Shakra, 1978 ; Helmerick and Pfeifer, 1954; Sharma 1973 ; and Thill et al., 1979). Powell and Pfeifer (1956) stated that the use of mannitol solutions to test drought resistance is a simple, easily repeated test which gives a relative measurement of any differences among selections for this seedling characteristic.

With the regular use of polyethylene glycol (PEG) and mannitol as osmotic agents in seed germination experiments, knowldge about their osmotic stability is required. Thill et al. (1977) tested the stability of 28-day-old, and freshly prepared solutions of the two osmotic agents, with water potentials ranging from -3.5 to -18.0 bars. They found that the osmotic potential of different mannitol and PEG solutions did not change with time and that the percent and rate of germination of wheat was the same in the 28-day-old and freshly prepared mannitol and PEG solutions.

Helmerick and Pfeifer (1954) used mannitol solutions to obtain moisture stress with winter wheat. They reported that, as moisture stress increased, germination was delayed and reduced, and the rate of seedling growth also was reduced; their results paralleled a field study. Similarly, Rodger et al. (1957) found that as osmotic tension of germination (D-mannitol) increased, speed and percentage of germination of several alfalfa (*Medicago sativa* L.) varieties decreased. Also working with alfalfa, Dotzenko and Dean (1959) concluded that the ability of varieties to germinate under extreme drought stress is heritable.

Williams et al. (1967) and, Parmer and Moore (1968) used carbowax 6000, mannitol, and sodium chloride for simulating drought conditions in germination studies of corn (*Zea mays* L.). Their results indicated that increased osmotic potential levels progressively delayed and reduced germination. Similar results were obtained by Sharma (1973) who studied the effect of simulated drought on seed germination of several pasture species; he simulated the drought conditions by using sodium chloride (NaCl), D-mannitol and polyethylene glycol (PEG, 20 000 m.wt). The results indicated that the rate and total germination of all the species declined with decreasing levels of water potential. However, the extent of such reduction varied considerably among species and with the type of osmotic medium.

Wright (1971) reported that D-mannitol was effective in simulating drought conditions for germination and early seedling growth of several grasses and cereals. Jaradat (1979) used mannitol to simulate moisture deficits, to study the germination responses of several wheat cultivars. He found that increasing moisture tension has caused significant reductions in the germination percentages, speed of germination and length of root system. He also found that local varieties had longer root systems with a lower shoot to root ratio. Similarly, Navale et al. (1982) studied the germination and early seedling growth of five chickpea (Cicer arietinum L.) cultivars under different osmotic concentrations of D-mannitol. They found that the germination percentage and speed as well as early root (radicle) and shoot (Plumule) growth decreased with increase in osmotic concentration.

Somers et al. (1983) used polyethylene glycole 20,000 aquous solution of different concentrations to study the germination responses, as a screening technique for the selection of sunflower (Helianthus annuus L.) cultivars ability to emerge under low moisture conditions. The results indicated that the germination percentage of the sunflower cultivars decreased with increasing moisture stress.

Much work was done in the laboratory, but the results have been rarely tested under drought conditions in the field.

3. MATERIALS AND METHODS

A study was conducted to evaluate the response of ten lentil genotypes to drought. The study consisted of three different experiments, in which the same lentil genotypes were used.

The following is a description of these experiments:

3.1. EXPERIMENT I. Response of lentil to water gradient using sprinkler irrigation system:

The experiment was conducted during 1984/85 and 1985/86 growing seasons, at Ramtha research station in the northern part of Jordan. The station is located at 32^{o}: 34 N Latitude, 36^{o}: 01 E Longitude, with an elevation of 590 m. The annual precipitation of the area averaged 210 mm for the period of 1976/77 to 1985/86. The soil of the experimental site is silty clay in texture, with apparent specific gravity ranging from 1.40 at the surface to 1.66 at the 60 cm depth.

Ten lentil genotypes were subjected to variable levels of drought by supplying a decreasing gradient of water through a line source sprinkler system (Hanks et al, 1976), in which the rows of lentil are planted perpendicular to the irrigation line. Different water levels in right angles of the sprinkler line had resulted in a continuous variable design. The characteristic feature of the system is the application of water at a maximum rate nearest the line source and an approximate linear decrease in application to zero, at about 8 meters perpendicularly

Table 1. Irrigation record for each treatment during the 1984/85 and 1985/86 growing seasons.

Irrigation date	Growth stage	Water level +			
		W1	W2	W3	W4
1984/85 season		mm			
2/12/84	Seedling	7.5	12.2	16.9	24.0
16/1/85	Preflowering	6.6	11.2	15.4	19.8
17/4/85	Pod setting	6.3	10.1	16.0	24.0
1985/86 season					
22/1/86	After planting	7.9	15.4	18.7	20.8
2/2/86	Seedling	4.9	8.8	10.1	12.2
6/3/86	Seedling	9.6	12.3	16.5	23.9
26/3/86	Preflowering	7.8	12.1	15.0	19.1
17/4/86	Preflowering	12.9	26.5	33.3	38.6
5/5/86	Pod setting	5.9	8.8	12.0	16.3

+ W0 Treatment was not mentioned because it received no irrigation.

Table 2. Amount of applied water and rainfall received at five locations on the different irrigation gradient during the 1984/85 and 1985/86 seasons.

Variable	Water levels				
	W0	W1	W2	W3	W4
Seasonal amount of water received (mm).					
+ 1984/85 season					
a) Irrigation (3)*.	-----	20.4	33.5	48.3	67.8
b) Rainfall.	243.5	243.5	243.5	243.5	243.5
Total amount of water received (mm).	243.5	263.9	227.0	291.8	311.3
+ 1985/86 season					
a) Irrigation (6).	-----	49.0	83.9	105.6	130.9
b) Rainfall**.	164.3	164.3	164.3	164.3	164.3
Total amount of water received (mm)	164.3	213.3	248.2	269.9	295.2

* Figures in parentheses refer to number of irrigation.

** During 1985/86 season, 55.1 mm of the rainfall was received before planting.

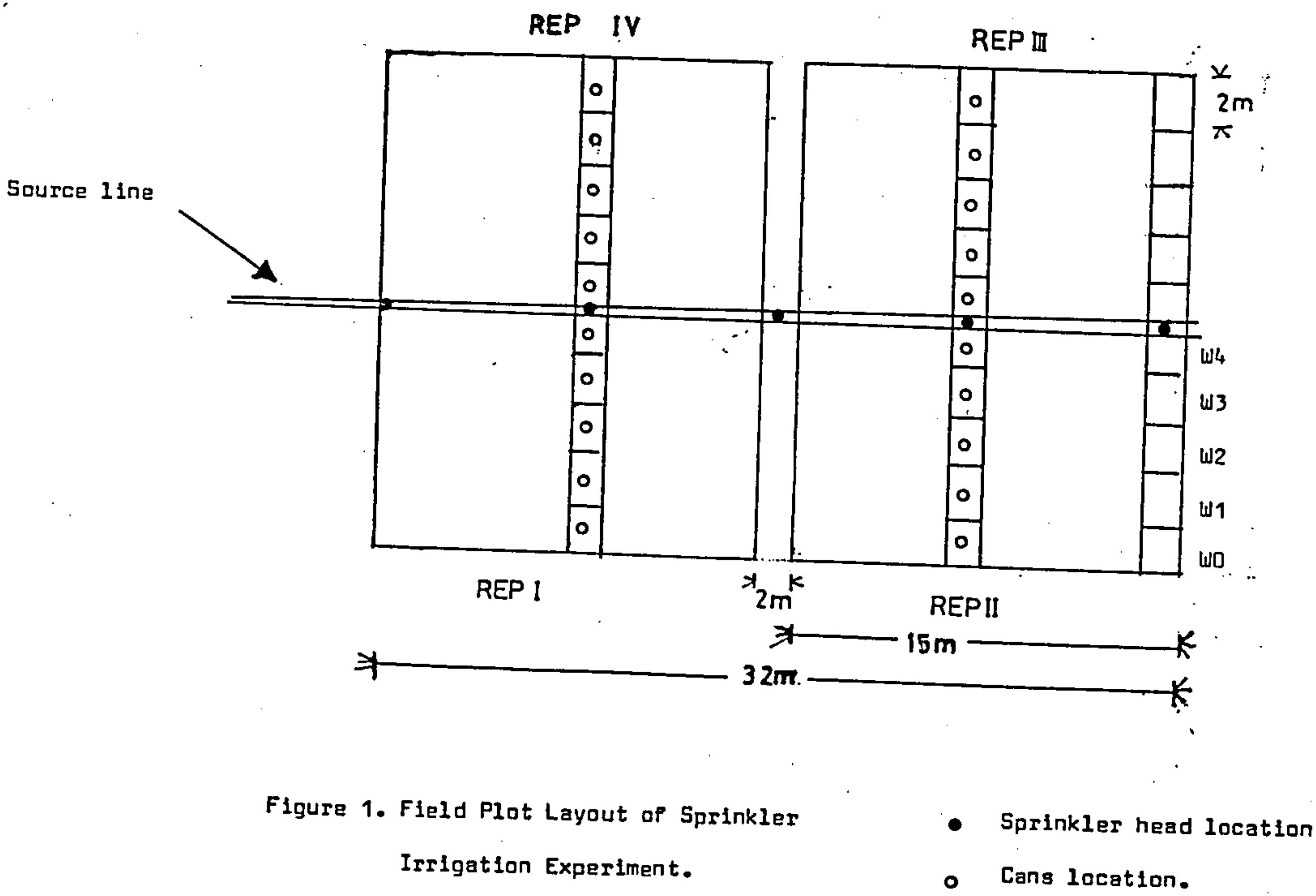

Figure 1. Field Plot Layout of Sprinkler Irrigation Experiment.

from the pipeline. The experimental area was divided into two parts east and west of the line. The distance of 10 meters perpendicular from the line source was divided into five segments of irrigation levels (W4, W3, W2, W1 and W0), that were replicated twice on each side of the line source, which resulted in four replications for each treatment.

Seeds were planted in rows perpendicular to the line source. Each sub-plot consisted of 6 rows, 25 cm apart and 2 m long. Seeding was done by hand at the rate of 100 seed per row. The land was fertilized prior to seeding with 30 kg ha^{-1} of N in the form of ammonium sulfate, and 60 kg ha^{-1} of P_2O_5 in the form of triple super phosphate. The experiments were hand weeded when necessary. Water was applied during long periods of no rain. The irrigation record for each treatment during both seasons is presented in Table 1 .

Each side of the line source received a nearly identical water application to its symmetrical counter part on the other side. Although attempts were made to irrigate during calm hours, wind drift was a problem, which was reflected on the amount of irrigation received, especially during the 1984/85 season. The amount of water applied at each irrigation was measured for every level of water and for the four replications using catch cans. Amount of irrigation water applied under different treatments along with the precipitation amounts received during the two growing seasons are presented in Table 2. The general lay-out of the experiment is presented in Figure 1.

The ten lentil genotypes evaluated in this study, were selected on the basis of their morphological and agronomical characteristics. The genotypes used with their pedigree and origin are listed in Table 3 . More detailed information about some agronomical characteristics of them are presented in Table 1 appendix A .

Sowing was done on November 8, 1984 during 1984/85 growing season. However, in the 1985/86 growing season, plots were infested with volunteer barley, and therefore the experiment was replanted in adjacent field on January 18, 1986 .

Plant samples were collected at flowering stage by using a hand driven fork to a depth of about 30 cm, plants were removed with whole root system intact. Fifteen competitive plants were sampled from the second row of each subplot, washed gently with water to remove soil particles from the roots. The following measurements were recorded on the fifteen plants and data were converted to per plant:

1. Plant height (cm), measured by streching the plant to get the maximum length, excluding the root system.
2. Number of primary branches per plant.
3. Number of secondary branches per plant.
4. Number of nodules per plant.

At maturity, yield and yield components were studied. Fifteen plants were randomly selected, and harvested from each subplot. The following measurements were recorded on the fifteen plants and data converted to per plant:

Table 3. Number, origin and pedigree of the ten lentil genotypes used in the study.

No.	Genotype No. (ILL, UJL or selection).	Country of origin	Pedigree Information
1	UJL 405	--------	79 S 4 X pull 9, selection no. 4 in 1979 from a cross between Chilian X Precoz (cross was made in Pullman WA 1977).
2	UJL 289	Jordan	Selection from UJL 270 collected from Wadi Musa/ Jordan.
3	76 TA 66088	Iran	ILL 223 .
4	ILL 4401	Syria	Syrian local small.
5	UJL 176	Jordan	Local collection from Maddaba/Jordan.
6	UJL 510	-------	79 S 31 X pull 9, selection no. 31 from a cross between Chilian X Precoz (cross was made in Pullman WA 1977).
7	ILL 4400	Syria	Syrian local large.
8	78 S-26013	Jordan	ILL 16 .
9	Precoz	Argentina	ILL 4605 .
10	Winter lik-51	Turkey	ILL 1880 .

a. Number of pods per plant.

b. Number of seeds per pod.

c. Weight of 100 seeds.

At crop maturity, and on plot scale, the 4 central rows of each subplot were harvested, leaving two rows from each side as a border; also a 1/2 meter distance from each edge of the plot was left unharvested. The following traits were measured on the harvested plot and data then converted to kg ha^{-1} :

1. Biological yield (kg ha^{-1}): the dry weight of total vegetative growth harvested by pulling.
2. Grain yield (kg ha^{-1}).
3. Straw yield (kg ha^{-1}); measured by subtracting the grain yield from the biological yield.
4. Harvest idex (%); measured by dividing grain yield by biological yield, and then multiplying by 100 .

Soil Moisture Determination:

Intensive soil moisture studies were carried out to determine the evapotranspiration and the water use efficiency of two genotypes; UJL 176, and ILL 4400 . Soil moisture was measured directly using the gravimetric method, then values were converted on volumetric basis (percentage moisture content), and then converted to mm of water by using soil apparent specific gravity.

Soil samples which represent different depths (0-15, 15-30, 30-45, and 45-60 cm) were taken forty eight hours after effective rain (> 17 mm), after irrigation and immediately before next irrigation. Soil samples were weighed, and then dried in the oven at 105 C^{o} for 24 hours. Soil water depletion was taken as the difference between the initial and the final water content measurements from each depth. This amount represent the depth of water extracted by plant roots and lost by evaporation (Evapotranspiration, ET) (Karajeh, 1983).

Statistical Analysis:

The nature of the line source does not allow for randomizing and therefore, the use of statistical analysis will be restricted. However, the arrangement of water levels could be considered one way of randomizing (Hanks et al., 1980). Therefore, lentil genotypes randomized and replicated perpendicularly to the irrigation line, can be statistically analysed according to split-plot design. In this case lentil genotypes are considered as the main plot and the irrigation levels as the subplot.

3.2. EXPERIMENT II. Stability Of Yield Components In Lentil:

Ten lentil genotypes were tested in eight different environments during 1984/85 and 1985/86 under rainfed conditions at three locations in Jordan. The locations were Jubeiha with average annual rainfall of 458 mm (for the period 1976/77 to 1985/86), Ramtha with average annual rainfall of 210 mm (for the period 1976/77 to 1985/86), and Maru with average annual rainfall of 370 mm (for the period 1980/81 to 1985/86).

However, the experiment was grown at two dates; normal sowing date, and late sowing in order to induce a large variation in the environmental conditions by exposing tested genotypes to late season drought stress.

The planting dates were as follows:

	1984/85	1985/86
Ramtha location:		
Normal date (D_1)	24/11/84	12/11/85
Late date (D_2)	10/ 2/85	18/ 2/86
Jubeiha location:		
Normal date (D_1)	20/12/84	11/11/85
Late date (D_2)	11/ 2/85	19/2 /86
Maru location:		
Normal date (D_1)	25/11/84	-----
Late date (D_2)	28/ 1/85	-----

Precipitation varied considerably among locations, years, and months. Detail monthly rainfall during the two growing seasons at the three locations are presented in Figures 2, 3 and 4 . The lentil genotypes used in this study were the same genotypes that were evaluated in experiment I (Table 2).

A randomized complete block design with 4 replications was used. Each plot consisted of 4 rows, 4 m long and 25 cm a part. Seeding was done by hand at the rate of 200 seed per row. The fertilization application was similar to that of experiment I.

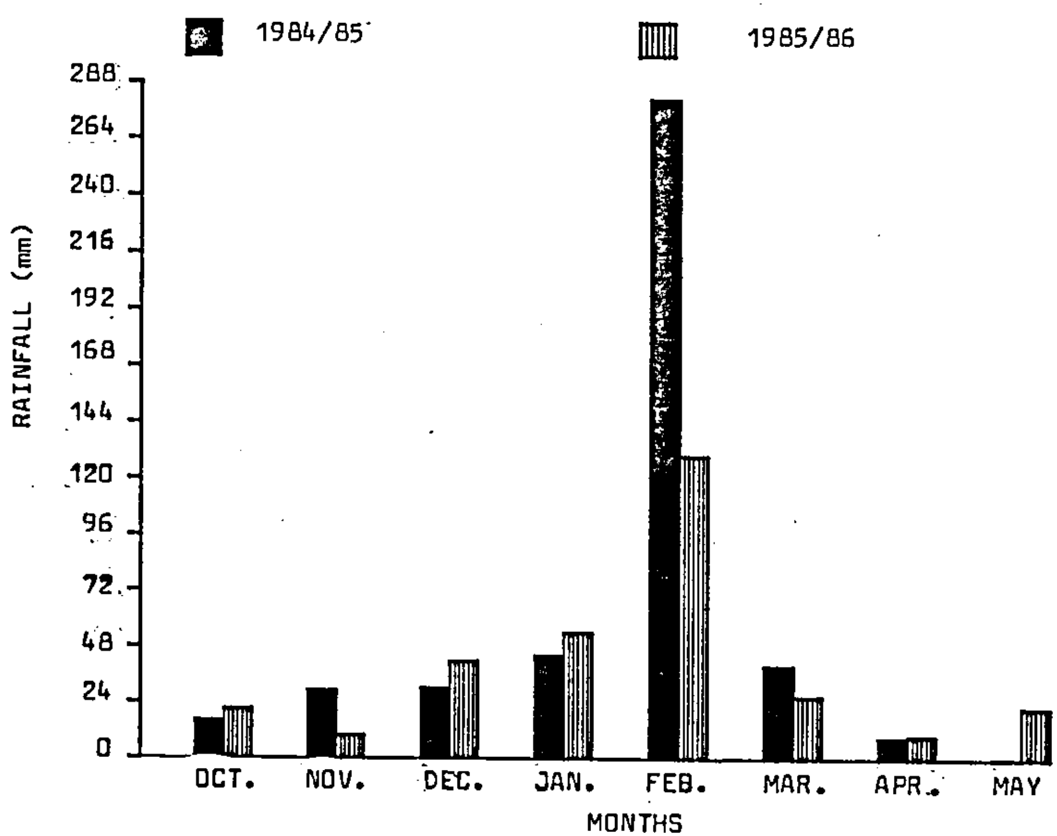

Figure 3. Monthly rainfall distribution during the 1984/85 and 1985/86 growing seasons at Jubeiha/Jordan.

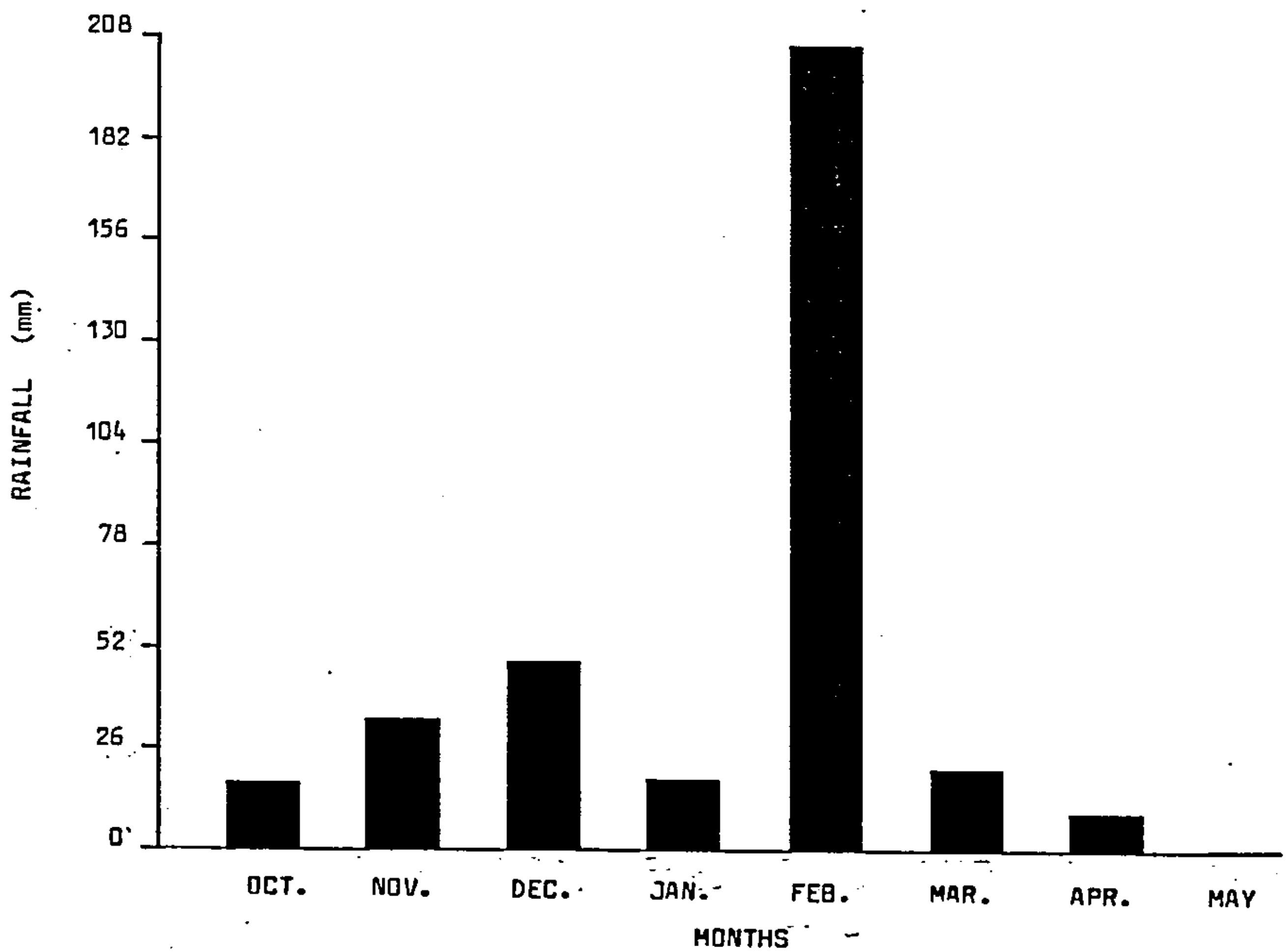

Figure 4. Monthly rainfall distribution during the 1984/85 growing season in Maru/Jordan.

At maturity, yield and yield components were studied. Ten plants were randomly selected, and harvested from each plot. The following measurements were recorded on the ten plants and data was converted to per plant:

a. Number of pods per plant.

b. Number of seeds per pod.

c. Weight of 100 seeds.

At crop maturity, 3 meters of the two central rows of each plot were harvested, leaving one row from each side as a border; also a 1/2 meter distance from each edge of the plot was left unharvested. The following measurements were recorded on per plot and data then converted to kg ha^{-1} :

1. Biological yield (kg ha^{-1}).
2. Grain yield (kg ha^{-1}).
3. Straw yield (kg ha^{-1}), measured by subtracting the grain yield from the biological yield.

Since the late planting in Ramtha location during both growing seasons was completely damaged due to severe drought stress, the data were recorded in eight environments.

Stability parameters were computed by the method suggested by Eberhart and Russell (1966).

3.3. EXPERIMENT III. Effect of Simulated Moisture Stress On Lentil Seed Germination:

Seeds of the ten lentil genotypes, were germinated under four moisture tensions, namely, 0,5,10 and 15 atm. The test was carried out using a stainless steel screen in plastic pots of the following dimensions (37 X 15 X 10 cm). A split-plot design with three replications were used, where the moisture tensions represented the main plot treatments and the genotypes as the sub plot treatments. Experimental plot consisted of 5 seeds. Moisture tensions were induced by using D-mannitol in the laboratory germination medium (The chemical and physical properties of this compound are presented in appendix B.). Distilled water was used for the 0 tension. The amounts of mannitol needed to produce the required moisture tensions were calculated from the following formula given by Helmerick and Pfeifer (1954): P= gRT/mv, where P= osmotic pressure in atmosphers, g= grams of mannitol required, R= 0.0825 liter atmospheres per degree per mole, T= absolute temperature, M= molecular weight of mannitol, V= volume in liters. The seeds were treated with a fungicide (terrachlor) to prevent seed decay.

Seeds were incubated in darkness at 20 $\pm$ 1 C^{o} for 14 days period. Germination counts were made daily. Seeds were considered germinated when a primary root was produced and the shoots were 5 mm long. At the end of the test period, the data were recorded on each individual plant on the following: root length (cm), root fresh weight (mg), shoot length (cm), and shoot fresh weight (mg).

The following parameters were studied:

A. Germination percentages: were obtained by counting the number of germinated seeds daily until the 14th day.

B. Speed of germination: was determined by using the Vigor Index (VI) formula (Maguire, 1962), $VI = \sum NX/DX$, where NX= the number of seeds germinated on X day and DX= number of days from beginning of germination test to X day .

C. Relative Drought Tolerance Indices 1 and 2 (RDTI): RDTI-1, is defined as a ratio of the speed of germination in a given osmotic stress to the speed of germination in distilled water. Similarly, RDTI - 2 is the ratio of the total germinated seeds under a given osmotic stress to the total germinated seeds in distilled water (Bhatt, 1979). These two indices were used to quantify relative drought tolerance of the genotypes.

D. Root growth: was measured on each individual plant from all treatments, and the obtained values were converted to rate of root growth per seedling per day.

4. RESULTS AND DISCUSSION

The results will be presented and discussed under four sections, as following:

4.1. Response of lentil to water gradient using sprinkler irrigation system.

4.2. Stability of yield and yield components in lentil.

4.3. Effect of simulated moisture stress on lentil seed germination.

4.4. Comparison between yield in the field trials and some characters studied in the laboratory test.

4.1 Response Of Lentil To Water Gradient Using Sprinkler Irrigation System:

4.1.1. The effect of water gradient on lentil yield, agronomic character and nodulation:

4.1.1.1. Grain yield:

Grain yield is the major product of the lentil crop which is directly utilized, therefore, increasing grain yield production is the first objective in lentil improvement.

Significant differences for grain yield were found among the 10 lentil genotypes during the two growing seasons (Table 4). In 1984/85 growing season, Winter lik-51 produced the greatest yield followed by ILL 4401 and ILL 4400 (733, 679 and 677 kg ha^{-1} , respectively). However, in the 1985/86 season, UJL 405, Winter lik-51 and ILL 4401 were the highest yielders and produced 389, 369 and 350 kg ha^{-1}, respectively. Genotypic differences for grain yield in response to water

Table 4. Effect of genotype and water level on grain yield (kg ha^{-1}) of lentil grown in Ramtha during the 1984/85 and 1985/86 growing seasons.

Treatment	Growing Season	
	1984/85	1985/86
Genotypes:		
UJL 405	640 bc*	389 a
UJL 289	643 bc	253 c
76 TA 66088	571 d	222 cd
ILL 4401	679 b	350 ab
UJL 176	648 bc	242 c
UJL 510	419 f	224 cd
ILL 4400	677 b	181 d
78 S-26013	615 c	310 b
Precoz	474 e	206 cd
Winter lik-51	733 a	369 a
Water levels +		
W0	374 e	57 e
W1	519 d	142 d
W2	630 c	282 c
W3	708 b	384 b
W4	819 a	509 a

* Means within each column for the same treatment followed by the same letters are not significantly different at the 5 % probability level following the Duncan's Multiple Range Test (DMRT).

\+ Water levels for both growing seasons:
1984/85; W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm
1985/86; W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4: 295.2mm

supply were also observed by Panwar and Paliwal (1975).

Grain yield in the ten genotypes decreased sharply from the highest moisture (W4) to the lowest (W0) during both seasons (Table 4). Over all genotypes, grain yield increased significantly as the moisture was improved. This is mainly due to increase in number of pods per plant occuring on larger plants. Singh et al. (1983) indicated that irrigation increases the availability of water in the soil profile to the plant and thereby enhances almost all physio - chemical processes in plants that ultimately contribute towards additional grain production. Similar results were reported by Panwar and Paliwal (1975), and Saraf and Baitha (1979) on lentils, and by El-Nadi (1975) on beans.

Although more water was applied during 1985/86 season, grain production in 1984/85 was highest. This was due to the amounts of rainfall received during this season, where 243.5 and 164.3 mm were received during 1984/85 and 1985/86 seasons, respectively (Table 2). Also late planting in 1985/86 season, may have contributed to lower yields than in the previous season.

The interaction between genotype and water level was significant for grain yield during both growing seasons (Table 1 appendix D). This significant interaction means that yield of some genotypes is reduced to a greater degree than other genotypes under water stress.

Begg and Turner (1976) have indicated varietal differences exist in the tolerance of grass species to severe moisture deficits.

Drought resistance is often determined as the percentage yield decline between stress and nonstress environments (Arnon, 1975). When this definition was applied to the genotypes under the present study, large yield differences between the ten genotypes at any given soil moisture stress treatment can be easily detected. For instance, in 1984/85 season, the fall in the level of water supply from the highest (W4) to the lowest (W0) level caused a reduction in grain yield of all genotypes, however, the least reduction were recorded with Precoz, 76 TA 66088, UJL 405 and Winter lik-51, where the reduction percentage was 83, 90, 98 and 102 %, for the four genotypes, respectively (Table 5). In 1985/86 season, however, genotypes 76 TA 66088, Winter lik-51 and UJL 405 were less sensitive to water stress and had grain yield reduction percentage of 597, 700 and 777%, respectively (Table 6); indicating the ability of these genotypes to resist drought over the other tested genotypes.

Grain yield was positively and significantly correlated with the amount of water applied plus rainfall for all the genotypes tested; the coefficient of determination (r^2) ranged from 0.79 to 0.92 for both growing seasons (Tables 7 and 8). The high values of the coefficients indicate that the additional applied of water accounted for much grain production.

The relationship between grain yield and applied water plus rainfall was tested by first, second and third degree equations, the linear relationships were only found to be significant.

Table 5. Effect of water level and genotype on grain yield (kg ha^{-1}) of lentil grown in Ramtha during the 1984/85 growing season.

Genotype	Water level +					Yield reduction
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	412 r-t *	572 o	647 k-n	721 ij	851 c-e	107
UJL 289	371 tu	509 pq	655 k-n	797 e-h	882 b-d	138
76 TA 66088	282 s-u	505 pq	595 m-o	648 k-n	726 ij	90
ILL 4401	428 r-t	600 l-o	678 i-k	772 f-i	915 b	114
UJL 176	429 r-t	548 op	640 k-n	727 ij	900 bc	110
UJL 510	223 v	331 u	440 rs	505 pq	593 no	166
ILL 4400	416 r-t	542 op	739 h-j	808 e-g	879 b-d	111
78 S-26013	334 u	501 pq	662 kl	734 ij	844 c-e	153
Precoz	329 u	423 r-t	475 qr	541 op	602 l-o	83
Winter lik-51	463 r-t	658 k-m	766 g-i	831 d-f	935 a	102

* Means followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels are:
W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm.

Table 6. Effect of water level and genotype on grain yield (kg ha^{-1}) of lentil grown in Ramtha during the 1985/86 growing season.

Genotype	Water level +					Yield reduction
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	77 t-v*	221 m-p	409 e-h	562 b	675 a	776
UJL 289	47 v	163 p-s	256 mn	341 h-l	460 c-e	879
76 TA 66088	60 v	93 t-v	208 n-q	329 j-l	418 e-g	597
ILL 4401	69 uv	181 o-r	338 i-l	510 bc	651 a	843
UJL 176	35 v	96 s-v	222 m-p	373 f-k	487 cd	1291
UJL 510	54 v	137 r-u	234 m-o	323 kl	367 g-k	583
ILL 4400	35 v	97 s-v	145 q-t	217 n-p	413 e-g	1080
78 S-26013	60 v	142 q-t	401 e-i	441 d-f	506 b-d	743
Precoz	38 v	68 uv	236 m-o	290 lm	395 e-j	942
Winter lik-51	89 t-v	223 m-p	366 g-k	455 c-e	712 a	700

* Means followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels are:

W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4: 2952mm.

Table 7. Regression equations showing the relationship between grain yield ($kg\ ha^{-1}$) and water applied plus rainfall (mm) for 10 lentil genotypes grown in Ramtha during 1984/85 growing season.

Genotype	Regression equation	r^2
UJL 405	Y= -1014.56 + 5.975 X	0.83**
UJL 289	Y= -1443.78 + 7.532 X	0.85**
76 TA 66088	Y= -776.5 + 4.865 X	0.79**
ILL 4401	Y= -1236.02 + 6.911 X	0.90**
UJL 176	Y= -1171.72 + 6.571 X	0.86**
UJL 510	Y= -1055.43 + 5.321 X	0.86**
ILL 4400	Y= -1191.63 + 6.744 X	0.79**
78 S-26013	Y= -1409.37 + 7.307 X	0.90**
Precoz	Y= -606.1 + 3.899 X	0.83**
Winter lik-51	Y= -1473.46 + 7.964 X	0.92**

** Significant at 1 % level.

Table 8. Regression equations showing the relationship between grain yield (kg ha^{-1}) and water applied plus rainfall (mm) for 10 lentil genotypes grown in Ramtha during 1985/86 growing season.

Genotype	Regression equation	r^2
UJL 405	Y= -744.49 + 4.758 X	0.92**
UJL 289	Y= -478.82 + 3.074 X	0.92**
76 TA 66088	Y= -450.0 + 2.82 X	0.88**
ILL 4401	Y= -720.3 + 4.492 X	0.92**
UJL 176	Y= -599.2 + 3.533 X	0.88**
UJL 510	Y= -365.67 + 2.474 X	0.92**
ILL 4400	Y= -428.8 + 2.555 X	0.79**
78 S-26013	Y= -571.2 + 3.699 X	0.92**
Precoz	Y= -467.5 + 2.826 X	0.86**
Winter lik-51	Y= -690.54 + 4.449 X	0.90**

** Significant at 1 % level.

Among the 10 lentil genotypes, Winter lik-51, UJL 289 and 78 S-26013 showed the greatest yield response to applied water (b= 7.964, 7.532 and 7.307, respectively) . Each additional mm of water produced 7.964, 7.532 and 7.307 kg/ha for these genotypes, respectively (Table 7). On the other hand, Precoz and 76 TA 66088 genotypes showed the least yield response to applied water (b= 3.899 and 4.865, respectively). However, in 1985/86 season. UJL 405, ILL 4401 and Winter lik-51 genotypes showed the greatest yield response to applied water (b= 4.758, 4.492 and 4.449, respectively); whereas, genotypes UJL 510, ILL 4400 and 76 TA 66088 and Precoz showed the least response to applied water (b= 2.474, 2.555, 2.820 and 2.826, respectively). However, the genotype Winter lik-51 showed the greatest yield response to applied water a mong the tested genotypes for both growing seasons.

Figures 5 and 6 showed the response of two extreme genotypes (Winter lik-51 and Precoz) for grain yield to applied water during both growing seasons. During the first season there was a large divargence between the lines of linear response for the two genotypes (b= 7.964 and 3.889 for Winter lik-51 and Precoz, respectively). However, in 1985/86 season, less divergence between lines for the two genotypes were found; b= 4.449 and 2.826 for Winter lik-51 and Precoz, respectively. This indicates that lower response to applied water plus rainfall during 1985/86 season when compared with 1984/85 season. This is due to low amounts of rainfall received during 1985/86 season. These results are similar to those of Pandey _et al_. (1984 a) on their work with

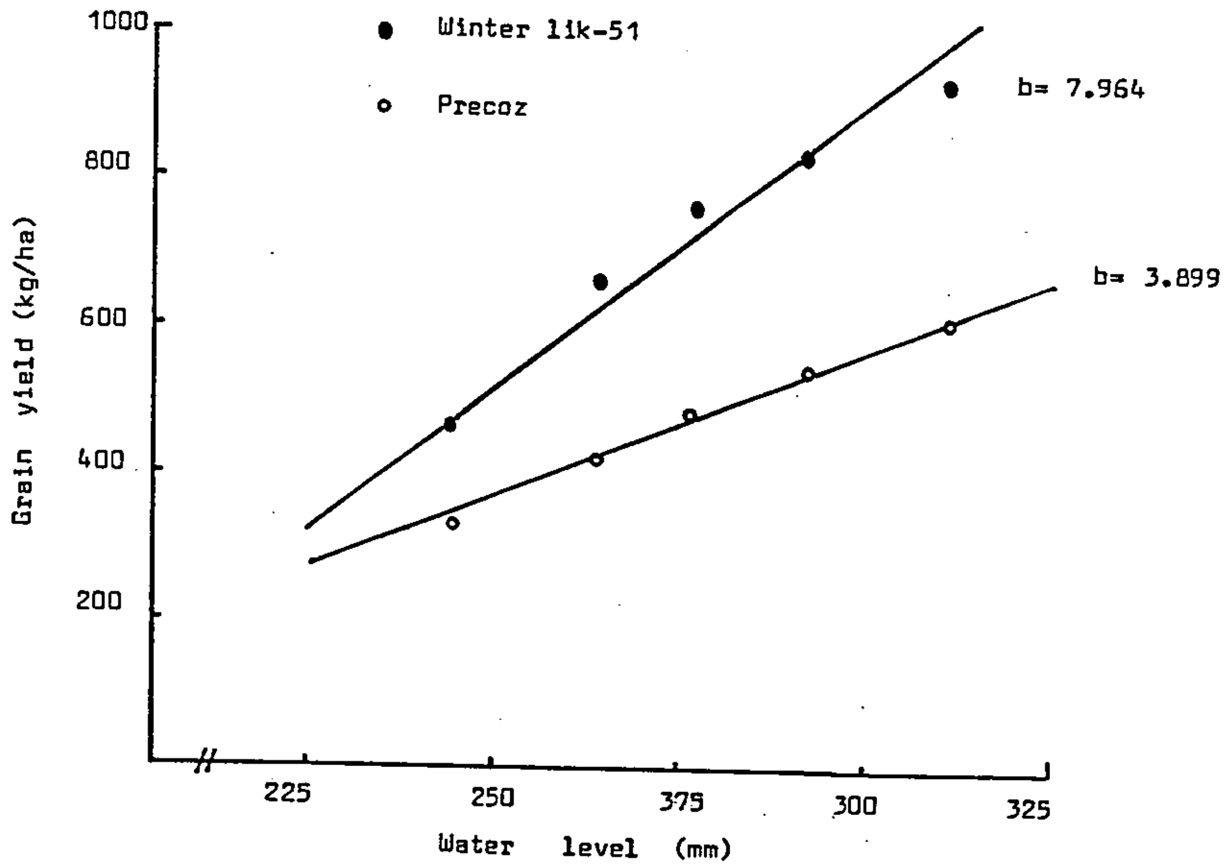

Figure 5. Response of two extreme genotypes (Winter lik-51 and Precoz) to applied water grown in Ramtha during the 1984/85 growing season.

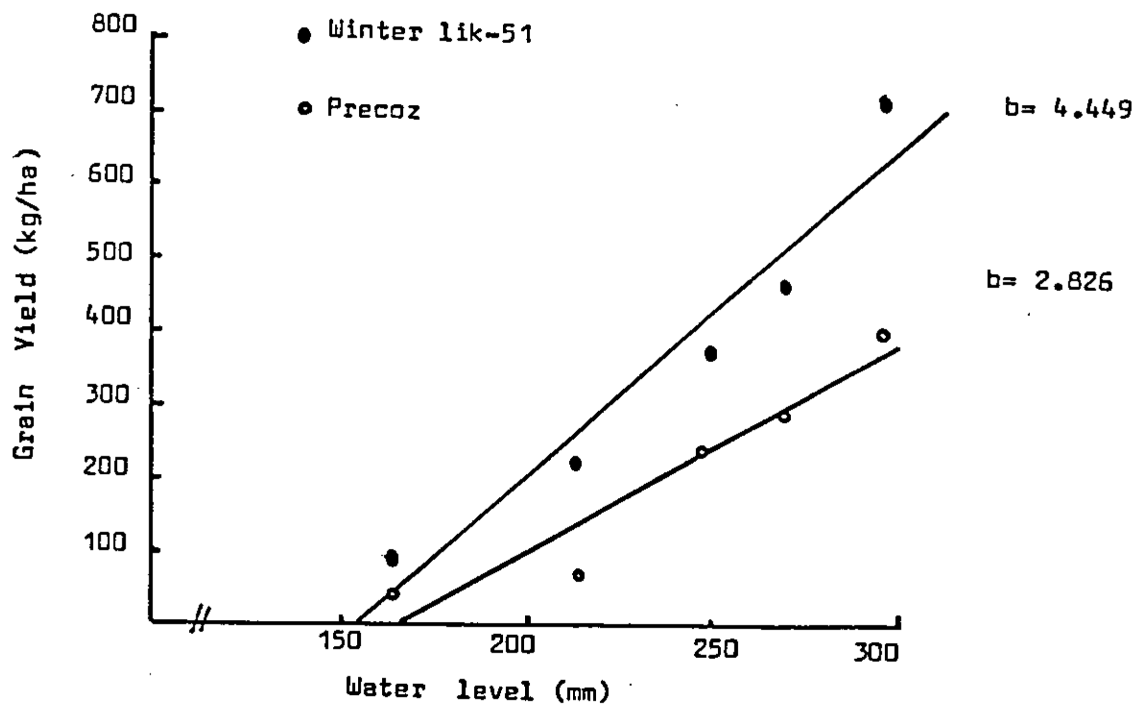

Figure 6. Response of two extreme genotypes (Winter lik-51 and Precoz) to applied water grown in Ramtha during 1985/86 growing season.

four grain legumes who found that grain yield exhibited a linear relationship with amount of water applied plus rainfall but with different magnitude (b ranged from 2.49 to 5.10).

4.1.1.2. Straw yield:

Straw is an important lentil product because of its high value as feed for livestocks.

The effects of genotype and water level on straw production are presented in table 9. The table revealed that there was a significant difference between the 10 lentil genotypes for straw production during both growing seasons. In 1984/85 season, the genotype Winter lik-51 produced the highest straw yield (1755 kg ha^{-1}) which was followed by 78 S-26013 and ILL 4400 genotypes (1675 and 1632 kg ha^{-1}, respectively). This is probably because these genotypes produced taller plants with more branching and consequently more dry matter. The lowest straw yields were produced by UJL 510 and Precoz (1053 and 990 kg ha^{-1}, respectively). Panwar and Paliwal (1975) indicated that varietal differences that exist in dry matter production of lentils in response to different irrigation regimes. However, in 1985/86 season, the genotypes Precoz, UJL 176 and UJL 510 significantly produced lower yields than the other genotypes.

Under high water level treatment (W4), the straw yield was the highest. This is due to better plant growth under the high moisture conditions which resulted in more accumulation of dry matter. Similar results were reported earlier on lentils (Hamoudi et et al. 1983; and Saxena and Wassimi, 1980).

Table 9. Effect of genotype and water level on straw yield (kg ha^{-1}) of lentil grown in Ramtha during the 1984/85 and 1985/86 growing seasons.

Treatment	Growing Season	
	1984/85	1985/86
Genotypes:		
UJL 405	1655 b*	1398 a
UJL 289	1489 c	1371 ab
76 TA 66088	1198 d	1365 ab
ILL 4401	1590 b	1232 bc
UJL 176	1282 d	1176 c
UJL 510	1053 e	1128 c
ILL 4400	1632 b	1396 a
78 S-26013	1675 ab	1501 a
Precoz	990 e	921 d
Winter lik-51	1755 a	1438 a
Water levels +		
W0	972 e	481 e
W1	1228 d	1018 d
W2	1403 c	1350 c
W3	1651 b	1651 b
W4	1905 a	1963 a

* Means within each column for the same treatment followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels for both growing seasons:
1984/85; W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm
1985/86; W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4. 295.2mm

There was significant interaction between genotypes and applied water for straw yield during both growing seasons (Table 2 appendix D).

In 1984/85 season, the genotypes Winter lik-51, UJL 289 and UJL 405 showed the least reduction in straw yield as a result of increased soil moisture stress level from W4 to W0 treatment (Table 10). However in 1985/86 season, the genotypes UJL 510, ILL 4400, 78 S-26013, UJL 405 and Winter lik-51 showed the least reduction in straw yield when soil moisture stress level increased from W4 to W0 treatment (Table 11), indicating the superiority of Winter lik-51 and UJL 405 genotypes over the other tested genotypes .

Mean straw yield of all genotypes at each water level was significantly related to amount of applied water. Coefficients of determination for straw yield and amount of water applied plus rainfall were varied with genotype; they ranged from 0.74 to 0.88 and from 0.81 to 0.92 during 1984/85 and 1985/86 seasons, respectively (Tables 12 and 13). The high coefficients indicated that the additional applied water resulted in more straw production. Pandey et al. (1984 b), working on four legume crops, found that shoot dry matter was linearly related to water applied. They also found that drought affected total dry weight adversely and that the relationship between shoot dry matter and applied water was varied with species. Similar results were obtained by Verma and Kalra (1981 b) on lentils.

However, when the relationship between applied water and straw production was tested for second and third degree equations, it was found to be not significant.

Table 10. Effect of water level and genotype on straw yield (kg ha^{-1}) of lentil grown in Ramtha during the 1984/85 growing season.

Genotype	Water level +					Yield reduction
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	1215 m-s *	1503 g-j	1612 g-h	1888 d-f	2057 bc	69
UJL 289	1119 p-u	1325 k-n	1537 g-i	1629 g	1835 ef	64
76 TA 66088	775 w	1045 tu	1272 c-q	1328 k-n	1570 gh	103
ILL 4401	1080 r-u	1283 l-p	1638 g	1904 c-f	2043 b-d	89
UJL 176	880 vw	994 uv	1218 m-r	1365 j-m	1951 c-e	122
UJL 510	535 x	1052 s-u	1110 q-u	1178 n-t	1390 i-c	160
ILL 4400	1151 o-u	1342 k-n	1412 i-l	1934 c-f	2321 a	102
78 S-26013	1150 o-u	1308 k-o	1455 h-k	2041 b-d	2423 a	111
Precoz	507 x	844 vw	992 uv	1276 l-p	1332 k-n	163
Winter lik-51	1310 k-o	1584 gh	1784 f	1929 c-e	2130 b	63

* Means followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels are:
W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm.

Table 11. Effect of water level and genotype on straw yield (kg ha^{-1}) of lentil grown in Ramtha during the 1985/86 growing season.

Genotype	Water level +					Yield reduction
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	504 v-x*	1052 r-u	1679 j-l	1782 f-i	1975 b-f	292
UJL 289	498 v-x	1000 s-u	1335 n-q	1852 e-g	2166 a-c	335
76 TA 66088	457 v-x	1234 p-r	1389 m-q	1726 g-j	2019 b-e	342
ILL 4401	453 v-x	938 u	1392 mg	1552 i-n	1828 e-h	304
UJL 176	340 wx	953 u	1254 o-r	1495 j-o	1837 e-h	440
UJL 510	477 v-x	939 u	1176 q-t	1335 n-q	1618 h-m	239
ILL 4400	546 v-w	1226 p-s	1410 m-q	1693 g-k	2107 b-d	286
78 S -26013	630 v	1260 o-r	1453 l-p	1967 c-f	2198 ab	249
Precoz	276 x	631 v	948 tu	1197 q-s	1555 i-n	463
Winter lik-51	587 vw	952 tu	1463 k-p	1911 d-g	2308 a	293

* Means within each column for the same treatment followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels are:
W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4: 295.2mm.

Table 13. Regression equations showing the relationship between straw yield (kg ha^{-1}) and water applied plus rainfall (mm) for 10 lentil genotypes grown in Ramtha during the 1984/85 growing season.

Genotype	Regression equation	r^2
UJL 405	Y= -1397.66 + 11.739 X	0.92**
UJL 289	Y= -1690.41 + 12.854 X	0.94**
76 TA 66088	Y= -1333.2 + 11.328 X	0.88**
ILL 4401	Y= -1282.75 + 10.561 X	0.94**
UJL 176	Y= -1455.37 + 11.046 X	0.94**
UJL 510	Y= -684.19 + 7.609 X	0.81**
ILL 4400	Y= -1284.14 + 11.254 X	0.92**
78 S-26013	Y= -135.61 + 11.827 X	0.90**
Precoz	Y= -1364.6 + 9.597 X	0.92**
Winter lik-51	Y= -1858.38 + 13.84 X	0.92**

** Significant at 1 % level.

Among the 10 lentil genotypes, 78 S-26013, ILL 4400 and UJL 176 showed the largest straw yield response to applied water plus rainfall (b = 19.215, 16.837 and 15.294, respectively). Each additional mm of water produced 19.215, 16.837 and 15.294 kg/ha for these genotypes showed the least response to applied water plus rainfall (b= 10.337 and 10.895, respectively).

However, in 1985/86 season Winter lik-51 and UJL 289 showed the greatest straw yield response to applied water plus rainfall (b= 13.84 and 12.854, respectively); whereas, genotypes UJL 510 and Precoz showed the least yield response to applied water plus rainfall (b= 7.609 and 9.597, respectively).

4.1.1.3. Harvest Index (%):

The harvest index will show the distribution of assimilate into grain and nongrain parts. The harvest index value was calculated by dividing the grain production over the production of straw plus grain and multipling by 100.

The effects of genotype and watěr level on harvest index are presented in Table 14. The UJL 176 and Precoz genotypes had the highest harvest index values (34 and 33 %, respectively) during 1984/85 season, whereas, 78 S-26013 genotype produced the lowest value of harvest index (27 %). However, the low harvest index of 78 S-26013 was obtained

Table 14. Effect of genotype and water level on harvest index (%) of lentil grown in Ramtha during the 1984/85 and 1985/86 growing seasons.

Treatment	Growing Season	
	1984/85	1985/86
Genotypes:		
UJL 405	28 de*	20 a
UJL 289	30 c	14 bc
76 TA 66088	32 b	13 c
ILL 4401	30 c	20 a
UJL 176	34 a	15 bc
UJL 510	28 de	16 b
ILL 4400	29 cd	10 d
78 S-26013	27 e	15 bc
Precoz	33 ab	16 b
Winter lik-51	29 cd	19 a
Water levels+		
W0	29 b	10 e
W1	30 a	12 d
W2	30 a	17 c
W3	30 a	19 b
W4	30 a	20 a

* Means within each column for the same treatment followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels for both growing seasons:
1984/85; W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm
1985/86; W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4: 295.2mm

because it produced lower grain yield and higher straw yield than UJL 176 and Precoz. This means that partitioning of assimilate into grain is more efficient in UJL 176 and Precoz than in 78 S-26013. In 1985/86 season, UJL 405 and Winter lik-51 gave the highest hervest index values (20 and 19 %, respectively), whereas ILL 4400 produced the lowest value (10 %). The difference between the two growing seasons for harvest index was due to different amount of rainfall precipitated. Hence, because water stress affected seed formation more than total dry matter yield, the harvest index declined as moisture stress increased. The moisture stress severity during 1985/86 season explained the low values of harvest index and proved that Winter lik-51 and UJL 405 genotypes to be superior in drought resistance over other tested genotypes.

The interaction between genotype and moisture level was significant (Table 3, appendix D).

Applied water had no significant effect on the harvest index during 1984/85 season, except for the driest treatment (W0) (Table 14). However, the reduction in harvest index with increasing moisture stress level from W4 to W0 treatment was greater with Winter lik-51 and UJL 289. In general, moisture levels had a slight effect on harvest index for the 1984/85 growing season. This was probably due to adequate rainfall that resulted in hampering the ability to impose a wide range of water deficit treatments.

Table 15. Effect of water level and genotype on harvest index (%) of lentil grown in Ramtha during the 1984/85 growing season.

Genotype	Water level +					Reduction from
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	26 i-k*	28 g-i	29 f-h	28 g-i	29 f-h	12
UJL 289	25 j-l	28 g-i	30 e-g	33 b-d	33 b-d	32
76 TA 66088	33 b-d	33 b-d	32 c-e	33 b-d	31 d-f	- 6
ILL 4401	28 g-i	31 d-f	29 f-h	29 f-h	31 d-f	11
UJL 176	33 b-d	35 b	35 b	34 bc	32 c-e	- 3
UJL 510	30 e-g	28 g-i	28 g-i	30 e-g	30 e-g	0
ILL 4400	27 h-j	29 f-h	35 b	30 e-g	28 g-i	4
78 S-26013	23 l	28 g-i	31 d-f	27 h-j	26 i-k	13
Precoz	39 a	33 b-d	33 b-d	30 e-g	31 d-f	-21
Winter lik-51	24 kl	30 e-g	30 e-g	30 e-g	32 c-e	33

* Means follod by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels are:

W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm.

Table 16. Effect of water level and genotype on harvest index (%) of lentil grown in Ramtha during the 1985/86 growing season.

Genotype	Water level +					Reduction from
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	13 i-l	17 e-h	20 c-e	24 ab	26 a	100
UJL 289	9 no	14 h-k	16 f-i	16 f-i	18 d-g	100
76 TA 66088	11 l-n	7 op	13 i-l	16 f-i	17 e-h	55
ILL 4401	13 i-l	16 f-i	20 c-e	25 a	26 a	100
UJL 176	9 no	9 no	15 g-j	20 c-e	21 cd	133
UJL 510	9 no	13 i-l	17 e-h	20 c-e	19 c-f	111
ILL 4400	6 p	8 n-p	9 no	11 l-n	16 f-i	167
78 S-26013	9 n-o	10 m-o	22 bc	19 c-f	19 c-f	111
Precoz	12 k-m	10 m-o	20 c-e	20 c-e	20 c-e	67
Winter lik-51	15 g-j	19 c-f	20 c-e	19 c-f	24 ab	60

* Means followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels are:

W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4: 295.2mm.

In 1985/86 season, harvest index declined as water application decreased in all 10 genotypes. However, the reduction was greater in UJL 405 and ILL 4401 than the rest tested genotypes (Table 16). This reduction in harvest index suggests that grain yield is more sensitive to water stress than total plant yield (Pandey et al., 1984 a).

4.1.1.4 Plant height:

Effects of different levels of water supply and genotypes on plant height are presented in Table 17. Significant differences in plant height were detected among the genotypes which were tested in response to applied water during both growing seasons. During 1984/85 season, plants of Precoz, 76 TA 66088 and UJL 510 were significantly shorter than the other tested genotypes. However, in 1985/86 season, plants of UJL 510, 78 S-26013, UJL 176 and Winter lik-51 were significantly taller than the other tested genotypes; whereas plants of ILL 4401, UJL 289 and Precoz were the shortest.

Results revealed that plant height of all the tested genotypes was signficantly decreased with increasing the moisture stress levels. Such reduction may be attributed to:

a) The general retardation of the enzymatic processes particularly those concerning with the reduction in photosynthetic rates (Kramer, 1969); and

b) Due to the adverse effects of reduced water content of processes related to decrease in turgor pressure (Henckel, 1964 and Kramer, 1969).

Table 17. Effect of genotype and water level on plant height (cm) of lentil grown in Ramtha during the 1984/85 and 1985/86 growing seasons.

Treatment	Growing Season	
	1984/85	1985/86
<u>Genotypes</u>		
UJL 405	25.3 a*	20.1 bc
UJL 289	24.2 a	19.8 c
76 TA 66088	23.0 b	20.8 a-c
ILL 4401	24.1 a	19.8 c
UJL 176	24.4 a	21.2 ab
UJL 510	21.1 c	21.5 a
ILL 4400	24.8 a	20.5 a-c
78 S-26013	25.3 a	21.5 a
Precoz	25.5 b	19.6 c
Winter lik-51	24.7 a	20.9 a-c
<u>Water levels</u> +		
W0	20.8 e	15.8 e
W1	22.8 d	18.8 d
W2	24.0 c	20.8 c
W3	25.2 b	22.5 b
W4	26.9 a	24.5 a

* Means within each column for the same treatment followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels for both growing seasons:
1984/85; W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm
1985/86; W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4: 295.2mm

Table 18. Effect of water level and genotype on plant height (cm) of lentil grown in Ramtha during the 1984/85 growing season.

Genotype	Water level +					Reduction from
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	21.1 r-u *	25.5 d-i	25.3 e-j	26.4 b-h	28.2 ab	34
UJL 289	21.5 q-t	23.4 k-q	24.1 i-o	25.1 e-k	26.8 a-e	25
76 TA 66088	19.3 uv	22.0 p-s	23.1 l-q	24.2 i-o	26.6 a-f	38
ILL 4401	19.9 t-u	22.0 p-s	24.1 i-o	25.9 c-i	28.3 a	42
UJL 176	21.0 s-u	23.0 m-r	24.9 e-i	25.7 c-j	27.3 a-d	30
UJL 510	17.5 v	19.7 t-v	20.9 s-u	22.6 o-s	23.8 j-p	36
ILL 4400	22.3 o-s	22.8 n-s	24.7 i-m	26.4 b-h	27.9 ab	25
78 S-26013	21.5 q-t	24.7 g-m	25.8 c-i	26.8 a-e	27.5 a-c	27
Precoz	21.0 s-u	22.0 p-s	22.4 o-s	22.7 n-s	24.5 h-n	17
Winter lik-51	21.5 q-t	22.7 n-s	24.7 i-m	26.5 a-g	28.3 a	32

* Means followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels are:

W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm.

Concerning the interaction between applied water and genotypes, results indicated that the interaction effects on plant height were significant during 1984/85 growing season only (Table 4 appendix D).

Plant height of all genotypes decreased sharply when they were grown in the drier treatment (WO), but the reductions were least in Precoz, UJL 289 and ILL 4400 (Table 18). Verma and Kalra (1981 b) indicated that increased moisture supply contributed in enhancement of plant height.

4.1.1.5. Number of pods per plant:

Number of pods beared by lentil plants is very important in determining grain yield potential.

The number of pods per plant was the yield component most sensitive to increasing water stress and significantly increased with increasing applied water during both growing seasons which finally resulted in higher grain yield (Table 19). The improvement effect of irrigation on number of pods per plant was reported by many researchers working with lentils (Saraf and Baitha, 1979; Singh et al., 1983; Hamoudi et al., 1983; and Panwar and Paliwal, 1975) and by Herbert and Baggerman (1983), working with cowpeas.

It seems that the total number of pods produced will be the main criteria which will reflect the potential grain yield of the 10 genotypes under the different treatments. The results indicated that Winter lik-51, UJL 176, 76 TA 66088 and 78 S-26013 had the highest

Table 19. Effect of genotype and water level on number of pods(per plant) of lentil grown in Ramtha during the 1984/85 and 1985/86 growing seasons.

Treatment	Growing Season	
	1984/85	1985/86
Genotypes:		
UJL 405	23.6 ab*	12.9 ab
UJL 289	23.7 ab	12.0 bc
76 TA 66088	24.6 a	11.0 c
ILL 4401	22.6 b	12.4 b
UJL 176	24.7 a	13.1 ab
UJL 510	12.2 d	9.0 d
ILL 4400	18.6 c	7.6 e
78 S-26013	25.1 a	12.7 b
Precoz	22.3 b	12.1 bc
Winter lik-51	24.6 a	14.0 a
Water levels +		
W0	15.9 e	3.3 e
W1	19.3 d	6.3 d
W2	21.7 c	11.3 c
W3	25.1 b	16.4 b
W4	28.9 a	21.0 a

* Means within each column for the same treatment followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

+ Water levels for both growing seasons:
1984/85; W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm
1985/86; W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4: 295.2mm

number of pods per plant during 1984/85 season, whereas during 1985/86 season, Winter lik-51 had the highest number of pods, indicating the superiority of Winter lik-51 over the other tested genotypes. Genotypic differences in number of pods per plant in response to water supply was also observed by Panwar and Paliwal (1975).

Significant interaction between genotypes and water levels was detected during both growing seasons (Table 5 appendix D). In 1984/85 season, pod number of Winter lik-51, Precoz and UJL 176 in the driest treatment (W0) were 42, 65 and 66 % respectively, lower than those in the wettest treatment (W4) which showed the least reduction in pod number per plant (Table 20). However, during 1985/86 season, the least reduction was obtained by Winter lik-51, UJL 405, and 76 TA 66088 genotypes (467, 462, and 461 %, respectively, Table 21). Winter lik-51 responded positively to increased moisture supply and it was among the genotypes least affected by drought conditions, indicating the superiority of this genotype in drought resistance over the other tested genotypes. However, it must be indicated that higher number of pods per plant resulting in larger grain yields.

The reduction in pod formation in the driest plot was probably due to reduced flower production and also greater abortion of flowers. These observations are similar to those reported by many researchers working with different legume crops (Turk _et al._, 1980; Tabbada and Flores, 1982; and Pandey _et al._, 1984 a).

Table 20. Effect of water level and genotype on number of pods(per plant)of lentil grown in Ramtha during the 1984/85 growing season.

Genotype	Water level +					Reduction from
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	17.1 p-t*	21.0 k-n	22.4 i-l	25.3 f-h	32.2 a	88
UJL 289	15.5 s-u	17.7 o-s	24.2 g-j	28.8 c-e	32.3 a	108
76 TA 66088	18.9 n-q	22.2 j-m	23.3 h-k	26.1 e-g	32.3 a	71
ILL 4401	15.2 s-u	19.2 n-p	22.8 h-k	24.9 f-i	31.2 ab	105
UJL 176	18.2 o-r	21.9 j-m	25.2 f-h	27.9 c-e	30.2 b-d	66
UJL 510	8.8 x	10.6 wx	11.8 vw	13.4 uv	16.2 r-t	84
ILL 4400	12.3 vw	15.2 s-u	14.9 tu	23.4 h-k	27.1 d-f	120
78 S-26013	16.5 q-t	22.1 j-m	26.1 e-g	29.0 b-d	31.5 b	91
Precoz	17.1 p-t	20.1 l-o	21.8 j-m	24.1 g-j	28.3 c-e	65
Winter lik-51	19.7 m-o	23.0 h-k	24.3 g-j	28.4 c-e	27.9 c-e	42

* Means followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels are:
W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm.

Table 21. Effect of water level and genotype on number of pods (per plant) of lentil grown in Ramtha during the 1985/86 growing season.

Genotype	Water level +					Reduction from
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	3.9 u-y*	7.6 n-q	13.3 hi	17.8 ef	21.9 bc	462
UJL 289	2.7 xy	5.6 q-r	10.9 i-l	17.2 f	23.8 ab	781
76 TA 66088	3.6 v-y	6.0 p-u	8.9 l-n	16.3 fg	20.2 cd	461
ILL 4401	2.8 xy	6.4 p-t	12.1 i-k	16.2 fg	24.4 a	771
UJL 176	2.2 y	6.6 o-s	14.1 g-i	19.7 de	23.1 ab	950
UJL 510	3.0 xy	5.5 q-w	8.7 m-o	13.0 h-j	14.9 gh	397
ILL 4400	2.3 y	4.4 s-y	7.2 n-q	10.6 k-m	13.4 hi	483
78 S-26013	4.9 r-x	8.1 n-p	12.7 h-k	15.6 fg	22.3 ab	355
Precoz	3.3 w-y	5.5 q-w	11.1 jk	17.1 f	22.8 ab	591
Winter lik-51	4.3 t-y	7.1 n-r	14.3 g-i	20.0 cd	24.4 a	467

* Means followed by the same letters are not significantly different at the 5% probability level following the DMRT.

\+ Water levels are:
W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4: 295.2mm.

4.1.1.6. Number of Seeds per pod:

Soil moisture stress level significantly affected the number of seeds per pod in both growing seasons (Table 22). During 1984/85 season the number of seeds per pod was significantly higher in Winter lik-51 and ILL 4401 genotypes when compared with other tested genotypes. However, during the 1985/86 season, the number of the produced seeds per pod was the highest in Winter lik-51 and UJL 405 genotypes.

Averaged over all the genotypes, the number of seeds per pod significantly decreased with increasing soil moisture stress level, where all genotypes had 3% and 11% fewer seeds per pod in the driest (W0) treatment than in the wettest (W4) treatment during 1984/85 and 1985/86 seasons, respectively. The improvement effect of increasing supplied water for number of seeds per pod were reported by Hamoudi et al. (1983) working on lentil, and by Herbert and Baggerman (1983) working on cowpeas.

Significant interaction between genotypes and applied water levels for number of seeds per pod was detected only during 1984/85 growing season (Table 6 appendix D). Genotypes Precoz and 78 S-26013 showed the least reduction in number of seeds per pod with increased water stress level from W4 to W0 during 1984/85 season (Table 23). However, the number of seeds per pod was less influenced by water stress than were yield and pod number. Similar observations were reported on four legume crops by Pandey et al. (1984a).

Table 23. Effect of water level and genotype on number of seeds (per pod) of lentil grown in Ramtha during the 1984/85 growing season.

Genotype	Water level +					Reduction from
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	1.02 m *	1.02 m	1.02 m	1.03 k-m	1.04 j-m	2
UJL 289	1.04 j-m	1.06 j-m	1.03 k-m	1.03 k-m	1.02 m	-2
76 TA 66088	1.13 g-i	1.18 f-i	1.20 d-g	1.21 c-f	1.19 e-h	5
ILL 4401	1.24 c-f	1.28 b-d	1.38 a	1.27 c-e	1.36 ab	10
UJL 176	1.03 k-m	1.02 m	1.02 l-n	1.11 h-m	1.12 g-k	9
UJL 510	1.04 j-m	1.04 j-m	1.04 j-m	1.04 j-m	1.02 m	-2
ILL 4400	1.09 i-m	1.03 k-m	1.06 j-m	1.04 j-m	1.05 j-m	-4
78 S-26013	1.12 g-m	1.08 j-m	1.09 i-m	1.12 g-l	1.11 h-m	-1
Precoz	1.09 i-m	1.08 j-m	1.10 i-m	1.10 i-m	1.09 i-m	0
Winter lik-51	1.24 c-f	1.30 a-c	1.29 a-c	1.30 a-c	1.30 a-c	5

* Means followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels are:

W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm.

4.1.1.7. Hundred seed weight:

The effects of genotype and water level on the 100-seed weight are presented in Table 24.

The results indicated that there is a significant differences among the 10 genotypes tested in response to water stress level during both growing seasons; UJL 510 and ILL 4400 genotypes were significantly higher than that of other tested genotypes.

Soil moisture level significantly affected the 100-seed weight in both growing seasons (Table 24). In 1984/85 season, lower weight of seeds was obtained in the driest treatment (W0) when compared with that obtained in the wettest treatment (W4). However, in 1985/86 season, a change in 100-seed weight was less affected when compared with the previous season.

Significant interaction was detected between genotypes and water supply level for 100-seed weight during both seasons (Table 7, appendix D). Seed weight in 76 TA 66088, 78 S-26013 and ILL 4400 genotypes were 6, 6 and 8 %, respectively, lower in the driest treatment than in the wettest; showing the least affected when compared with other tested genotypes during 1984/85 season (Table 25). However, during 1984/85, the tested genotypes showed less change in seed weight when the soil moisture stress level was decreased from the lowest (W4) to the highest (W0), where the differences were not significant except for UJL 405 genotype (Table 26). This is probably attributed to that moisture stress may happened at the end of the growing season, so this reflected in seed

Table 24. Effect of genotype and water level on 100-seed weight (g) of lentil grown in Ramtha during the 1984/85 and 1985/86 growing seasons.

Treatment	Growing Season	
	1984/85	1985/86
Genotypes:		
UJL 405	5.0 b*	4.0 f
UJL 289	4.8 bc	4.7 d
76 TA 66088	3.6 d	3.5 g
ILL 4401	3.8 d	3.6 g
UJL 176	4.5 c	4.3 e
UJL 510	6.9 a	6.9 a
ILL 4400	6.6 a	6.4 b
78 S-26013	3.4 d	3.1 h
Precoz	5.1 b	5.3 c
Winter lik-51	3.8 d	3.8 f
Water levels +		
W0	4.4 d	4.7 a
W1	4.6 c	4.6 ab
W2	4.8 b	4.5 a-c
W3	4.9 b	4.4 c
W4	5.1 a	4.5 a-c

* Means within each column for the same treatment followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels for both growing seasons:
1984/85; W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm
1985/86; W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4: 295.2mm

Table 25. Effect of water level and genotype on 100-seed weight (g) of lentil grown in Ramtha during the 1984/85 growing season.

Genotype	Water level +					Reduction from
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	4.5 j-m	4.8 g-k	5.1 e-h	5.2 e-g	5.3 ef	18
UJL 289	4.4 k-n	4.5 j-m	4.9 f-j	5.0 f-i	5.3 ef	20
76 TA 66088	3.6 q-s	3.5 rs	3.6 q-s	3.5 rs	3.8 p-r	6
ILL 4401	3.7 p-s	3.7 p-s	3.7 p-s	3.8 p-r	4.0 n-q	8
UJL 176	4.1 m-p	4.3 l-n	4.7 h-l	4.5 j-m	4.9 f-j	20
UJL 510	5.9 d	6.8 bc	7.1 a-c	7.2 ab	7.4 a	25
ILL 4400	6.2 d	6.0 d	6.7 c	6.9 bc	7.0 a-c	13
78 S-26013	3.3 s	3.3 s	3.5 rs	3.5 rs	3.5 rs	6
Precoz	4.6 i-l	5.1 e-h	5.1 e-h	5.2 e-g	5.5 e	20
Winter lik-51	3.5 rs	3.6 q-s	3.8 p-r	3.9 o-r	4.0 n-q	14

* Means followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

+ Water levels are:
W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm.

Table 26. Effect of water level and genotype on 100-seed weight (g) of lentil grown in Ramtha during the 1985/86 growing season.

Genotype	Water level +					Reduction from
	Wo	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	4.4 j-n*	3.9 n-r	3.9 n-r	4.1 i-p	3.6 p-t	- 18
UJL 289	4.9 g-j	4.6 h-l	4.9 g-j	4.5 i-m	4.4 j-n	- 10
76 TA 66088	3.6 p-t	3.4 r-v	3.7 o-s	3.6 p-t	3.4 r-v	- 6
ILL 4401	3.6 p-t	3.6 p-t	3.7 o-s	3.5 q-u	3.4 r-v	- 6
UJL 176	4.3 k-n	4.2 k-o	4.1 l-o	4.0 n-q	4.7 h-k	9
UJL 510	6.9 bc	7.5 a	7.2 ab	6.3 d	6.6 cd	- 14
ILL 440	6.3 d	6.6 cd	6.4 cd	6.1 d	6.3 d	0
78 S-26013	3.0 uv	3.1 t-v	2.9 v	3.2 s-v	3.2 s-v	7
Precoz	5.6 e	5.0 f-i	5.3 e-g	5.1 e-h	5.5 ef	-2
Winter lik-51	4.1 l-p	4.0 n-q	3.4 r-v	3.7 o-s	3.7 o-s	-10

* Means followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels are:
W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4: 295.2mm.

size, therefore, larger seeds in driest treatment were obtained. Similar results were found due to water stress by Singh et al. (1983) working on lentils.

4.1.1.8. Number of primary branches per plant

The number of primary branches is an important character because it determines the architeture of the plant and its potential straw yield, number of reproductive nodes and hence grain yield.

Soil moisture stress level and genotype had significant effect on the number of primary branches per plant during both growing seasons (Table 27). The results indicated that number of primary branches per plant was remarkably improved with increased moisture level and ranged from 1.80 to 2.36 and from 1.34 to 2.15 for the lowest (W0) and highest (W4) moisture level during 1984/85 and 1985/86 season, respectively. The effect of increased applied water on number of primary branches per plant is attributed to the increased availability of water in the soil profile per plant, to improved plant growth and a commensurate enhancement in number of primary branches per plant as found by Singh et al. (1983) on lentils.

Genotypes ILL 4401, ILL 4400, 78 S-26013 and Winter lik-51 significantly produced the highest number of primary branches per plant during 1984/85 season. However, in 1985/86 season, Winter lik-51 and UJL 510 produced the highest number of primary branches per plant.

Table 27. Effect of genotype and water level on number of primary branches (per plant) of lentil grown in Ramtha during the 1984/85 and 1985/86 growing seasons.

Treatment	Growing Season	
	1984/85	1985/86
Genotypes:		
UJL 405	2.07 cd*	1.79 cd
UJL 289	2.13 bc	1.69 d
76 TA 66088	1.95 e	1.73 d
ILL 4401	2.24 a	1.77 cd
UJL 176	2.02 de	1.83 bc
UJL 510	2.03 c-e	1.91 ab
ILL 4400	2.24 a	1.78 cd
78 S-26013	2.21 ab	1.69 d
Precoz	1.96 e	1.70 d
Winter lik-51	2.23 ab	1.96 a
Water levels +		
W0	1.88 e	1.34 e
W1	2.01 d	1.56 d
W2	2.10 c	1.83 c
W3	2.18 b	2.05 b
W4	2.36 a	2.15 a

* Means within each column for the same treatment followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels for both growing seasons:
1984/85; W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm
1985/86; W0: 164.3mm W1: 231.3mm W2: 248.2mm W3: 269.9mm W4: 295.2mm

Table 28. Effect of water level and genotype on number of primary branches (per plant) of lentil grown in Ramtha during the 1984/85 growing season.

Genotype	Water level +					Reduction from
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	1.88 o-r	2.03 j-o	2.03 j-o	2.13 f-k	2.30 c-e	22
UJL 289	1.90 n-r	2.00 j-o	2.13 f-k	2.20 d-i	2.40 bc	26
76 TA 66088	1.80 p-r	1.93 m-q	1.95 l-p	2.00 j-o	2.08 h-m	16
ILL 4401	2.00 j-o	2.08 h-m	2.28 c-f	2.35 b-d	2.48 ab	24
UJL 176	1.75 r	1.90 n-r	2.03 j-o	2.10 g-l	2.30 c-e	31
UJL 510	1.88 o-r	1.95 l-p	2.03 j-o	2.08 h-m	2.23 d-h	19
ILL 4400	1.98 k-o	2.15 e-j	2.25 c-g	2.33 b-d	2.48 ab	25
78 S-26013	1.90 n-r	2.05 i-n	2.23 d-h	2.28 c-f	2.60 a	37
Precoz	1.78 qr	1.95 l-p	1.95 l-p	2.03 j-o	2.10 g-l	18
Winter lik-51	1.98 k-o	2.08 h-m	2.15 e-j	2.33 b-d	2.60 a	31

* Means followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels are:
W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm.

Table 29. Effect of water level and genotype on number of primary branches (per plant) of lentil grown grown in Ramtha during the 1985/86 growing season.

Genotype	Water level +					Reduction from
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	1.33 q-s *	1.73 k-o	1.93 f-m	1.85 g-n	2.13 b-g	60
UJL 289	1.28 q-t	1.35 q-s	1.83 h-o	2.05 c-j	1.95 f-l	52
76 TA 66088	1.05 t	1.63 n-o	1.78 j-o	1.93 f-m	2.25 b-e	114
ILL 4401	1.18 r-t	1.43 p-r	1.70 k-p	2.20 b-f	2.35 b	99
UJL 176	1.35 q-s	1.55 o-q	1.80 i-o	2.13 b-g	2.33 bc	73
UJL 510	1.65 m-p	1.68 l-p	1.98 e-k	2.20 b-f	2.03 d-j	23
ILL 4400	1.55 o-q	1.55 o-q	1.63 n-p	2.08 b-i	2.08 b-i	34
78 S-26013	1.15 st	1.28 q-t	1.78 j-o	2.13 b-g	2.13 b-g	85
Precoz	1.25 r-t	1.70 k-p	1.78 j-o	1.85 g-n	1.93 f-m	54
Winter lik-51	1.63 n-p	1.68 l-p	2.1 b-h	2.08 b-i	2.39 a	41

* Means followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels are:
W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4: 295.2mm.

Significant interaction was detected between amount of applied water and genotypes for the number of primary branches during both seasons (Table 8 appendix D). Genotypes 76 TA 66088, UJL 510 and Precoz showed the least reduction in number of primary branches per plant with increased water stress level from the W4 to W0 during 1984/85 season (Table 28). In 1985/86, however, UJL 510, Precoz and Winter Iik-51 showed the least reduction in number of primary branches with increased moisture stress level from W4 to W0 treatment (Table 29). These results indicated that Precoz and UJL 510 were superior over the other tested genotypes for this character.

4.1.1.9 Number of secondary branches per plant:

The importance of studying the secondary branches character is because on these branches, many pods and leaves are located. Secondary branches develop throughout the vegetative phase and therefore, their development is influenced by the prevailing environmental conditions. However, in the present study, significant effect of soil moisture level and genotype on this character was detected in both seasons (Table 30).

Averaged over all the genotypes, number of secondary branches per plant was closely related to amount of applied water, where the number of secondary branches ranged from 6.5 to 10.5 and from 3.1 to 10.4 in the driest (W0) and wettest (W4) treatments during 1984/85 and 1985/86 seasons, respectively. This could be explained by the fact that irrigation

Table 30. Effect of genotype and water level on number of secondary branches (per plant) of lentil grown in Ramtha during the 1984/85 and 1985/86 growing seasons.

Treatment	Growing Season	
	1984/85	1985/86
Genotypes		
UJL 405	8.4 bc*	6.8 a
UJL 289	9.4 a	7.2 a
76 TA 66088	7.7 c-e	6.4 a
ILL 4401	9.4 a	6.9 a
UJL 176	7.5 de	7.4 a
UJL 510	7.2 e	6.8 a
ILL 4400	8.1 cd	7.4 a
78 S-26013	8.3 c	8.1 a
Precoz	7.9 c-e	6.0 a
Winter lik-51	9.1 ab	7.4 a
Water level +		
W0	6.5 e	3.1 e
W1	7.1 d	6.0 d
W2	8.2 c	7.1 c
W3	9.2 b	8.7 b
W4	10.5 a	10.4 a

* Means within each column for the same treatment followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels for both growing seasons:
1984/85; W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm
1985/86; W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4: 295.2mm

Table 31. Effect of water level and genotype on number of secondary branches (per plant) of lentil grown in Ramtha during the 1984/85 growing season.

Genotype	Water level +					Reduction from
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	6.4 s-w*	7.2 o-u	8.2 k-r	9.0 f-m	11.5 bc	80
UJL 289	7.5 m-t	6.9 q-v	8.5 h-p	10.8 b-e	13.3 a	77
76 TA 66088	6.8 r-v	6.6 s-v	7.5 m-t	8.8 g-n	9.1 f-l	38
ILL 4401	7.2 o-u	7.9 k-s	9.4 e-k	10.8 b-e	11.9 b	65
UJL 176	6.3 t-w	7.0 p-v	7.4 n-t	8.2 k-r	8.7 g-o	24
UJL 510	5.1 w	5.8 u-w	7.6 l-t	8.4 i-q	9.1 f-l	78
ILL 4400	5.6 vw	7.0 p-v	7.6 l-t	9.9 d-i	11.3 b-d	102
78 S-26013	6.9 q-v	7.5 m-t	8.4 i-q	8.5 h-p	9.9 d-i	43
Precoz	6.3 t-w	7.0 p-v	7.8 l-t	8.3 j-r	10.2 c-g	26
Winter lik-51	6.8 r-v	8.5 h-p	9.8 e-j	10.0 d-h	10.5 b-f	58

* Means followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels are:
W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm.

increases the availability of water in the soil profile to the plant and thereby enhances the physio-chemical processes in plants that ultimately contribute towards additional dry matter production, therefore number of branches was enhanced. These results are in agreement with those reported by Verma and Kalra (1981 a) and Singh et al. (1983) on lentils.

Genotypes, on the other hand, affected this character, and ILL 4400, UJL 289 and Winter lik-51 produced significantly more secondary branches per plant during 1984/85 season, than the other genotypes. However, there was no significant differences between the tested genotypes during 1985/86 season.

Significant interaction was detected between water levels and genotypes for the number of secondary branches per plant only during 1984/85 season (Table 9 appendix D). Genotypes 76 TA 66088, UJL 176, 78 S-26013 and Winter lik-51 showed the least reduction in number of secondary branches per plant with a fall in water level from the highest (W4) to lowest (W0) during 1984/85 season (Table 31).

4.1.1.10. Number of nodules per plant:

As mentioned earlier lentil has the ability to fix atmospheric nitrogen , in a ssotiation with Rhizobium bacteria in root nodules.

Nodulation patterns were significantly affected by the amount of applied water during both growing seasons (Table 32). On the average, all genotypes had significantly fewer nodules per plant in the driest

Table 32. Effect of genotype and water level on number of nodules (per plant) of lentil grown in Ramtha during the 1984/85 and 1985/86 growing seasons.

Treatment	Growing Season	
	1984/85	1985/86
Genotypes:		
UJL 405	38.3 a*	27.4 a
UJL 289	36.7 ab	26.5 a
76 TA 66088	34.1 de	25.8 a
ILL 4401	35.7 b-d	27.0 a
UJL 176	35.6 b-d	27.5 a
UJL 510	33.4 e	27.1 a
ILL 4400	36.0 bc	26.2 a
78 S-26013	34.6 c-e	26.3 a
Precoz	33.6 e	25.8 a
Winter lik-51	36.9 ab	27.0 a
Water levels +		
W0	28.0 e	18.5 e
W1	32.0 d	22.8 d
W2	35.8 c	26.4 c
W3	39.0 b	30.8 b
W4	42.7 a	34.7 a

* Means within each column for the same treatment followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels for both growing seasons:
1984/85; W0: 243.5mm W1: 263.9mm W2: 277.0mm W3: 291.8mm W4: 311.3mm
1985/86; W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4: 295.2mm

treatment (W0) when compared with wettest treatment (W4). The lowest nodule number in the driest treatment (W0) may be attributed to stressed leaves being unable to supply photosynthate to nodules. Similar results were obtained by Saraf and Baitha (1982) on lentils, and Sprent (1972) on faba beans.

Genotypes UJL 405, Winter lik-51 and UJL 289 significantly possessed more nodules per plant during 1984/85 season. However, although differences between genotypes during 1985/86 were not significant, there was a trend of increased number of nodules by UJL 405, ILL 4400, UJL 510 and Winter lik-51 when compared with other tested genotypes.

Significant interaction between applied water and genotypes was found only during 1985/86 season (Table 10 appendix D). In this season, ILL 4401, ILL 4400, UJL 289 and Winter lik-51 genotypes showed the least reduction in number of nodules under rainfed conditions (W0) compared with the highest water level(W4) (Table 33).

Number of nodules per plant was found positively and significantly correlated with the amount of water supplied plus rainfall for all the 10 genotypes tested; r^2 ranged from 0.58 to 0.94 for the 1985/86 growing season.

Among the 10 genotypes tested, Precoz and 78 S-26013 showed the greatest response to applied water (b= 0.144 and 0.147, respectively), this means that any additional applied water the plants formed 0.144 and 0.147 nodules per plant per mm of added water for Precoz and 78 S-26013

Table 33. Effect of water level and genotype on number of nodules (per plant) of lentil grown in Ramtha during the 1985/86 growing season.

	Water level +					Reduction from
	W0	W1	W2	W3	W4	W4 to W0 (%)
UJL 405	19.0 r-t *	23.9 j-o	26.9 h-k	31.7 d-g	35.4 a-c	86
UJL 289	18.8 r-u	23.6 k-p	26.1 h-l	31.0 d-g	32.8 b-e	74
76 TA 66088	17.9 s-u	23.3 l-p	25.0 j-m	27.1 h-j	35.7 ab	99
ILL 4401	20.5 p-s	23.3 l-p	25.7 i-l	31.4 d-g	33.9 b-e	65
UJL 176	18.8 r-u	24.1 j-o	28.5 g-i	31.9 d-f	34.3 a-d	82
UJL 510	19.7 q-t	21.3 n-r	25.9 h-l	31.3 d-g	37.2 a	89
ILL 4400	18.9 r-t	23.6 k-p	26.6 h-l	29.0 f-h	32.8 b-e	74
78 S-26013	16.6 tu	21.2 o-r	26.4 h-l	31.7 d-g	35.6 ab	114
Precoz	15.7 u	22.4 m-q	24.5 j-n	32.2 c-f	34.3 a-d	118
Winter lik-51	18.7 r-u	21.8 m-r	28.5 g-i	30.8 e-g	35.2 a-c	76

* Means followed by the same letters are not significantly different at the 5 % probability level following the DMRT.

\+ Water levels are:
W0: 164.3mm W1: 213.3mm W2: 248.2mm W3: 269.9mm W4: 295.2mm.

Table 34. Regression equations showing the relationship between nodules number(per plant) and water applied plus rainfall (mm) for 10 lentil genotypes grown in Ramtha during 1985/86 growing season.

Genotype	Regression equation	r^2
UJL 405	Y= -1.85 + 0.123 X	0.86**
UJL 289	Y= -0.54 + 0.109 X	0.85**
76 TA 66088	Y= -2.44 + 0.118 X	0.81**
ILL 4401	Y= -2.07 + 0.105 X	0.79**
UJL 176	Y= -1.74 + 0.124 X	0.92**
UJL 510	Y= -3.88 + 0.127 X	0.58**
ILL 4400	Y= -1.97 + 0.102 X	0.90**
78 S-26013	Y= -8.82 + 0.147 X	0.94**
Precoz	Y= -8.44 + 0.144 X	0.85**
Winter lik-51	Y= -3.76 + 0.129 X	0.90**

** Significant at 1 % level.

respectively; whereas ILL 4400, ILL 4401 and UJL 289 genotypes showed the least response to applied water (b= 0.102, 0.105 and 0.109, respectively) during 1984/85 growing season (Table 34). Similar findings were reported by Zablotowicz et al. (1981) on cowpeas, and Matheny and Hunt (1983) on soybeans, on the varietal differences for nodule number in response to applied water.

4.1.2. Evapotranspiration and water use efficiency:

4.1.2.1. Evapotranspiration rate:

The 10-day intervals evapotranspiration rate (mm/day) for the highest irrigated water level (W4) for the two genotypes; UJL 176 and ILL 4400 in both seasons are presented in Figures 7 and 8. Throughout the growing season, ET rate increased with plant growth and development and then started to decline nearly after 130 days from emergence until maturity for 1984/85 season for both genotypes. The peak ET rate in 1984/85 season occured between 50 days and 130 days after emergence which coincided with the flowering and pod setting period during the end of March and the second half of April. The maximum ET rates were, 3.4 mm/day after 80 days and 3.0 mm/day after 90 days from emergence for ILL 4400 and UJL 176, respectively.

In 1985/86 season, maximum ET rates were 3.1 mm/day and 3.1 mm/day for ILL 4400 and UJL 176 respectively; both maximum values occured after 40 days from plant emergence. During this period high amounts

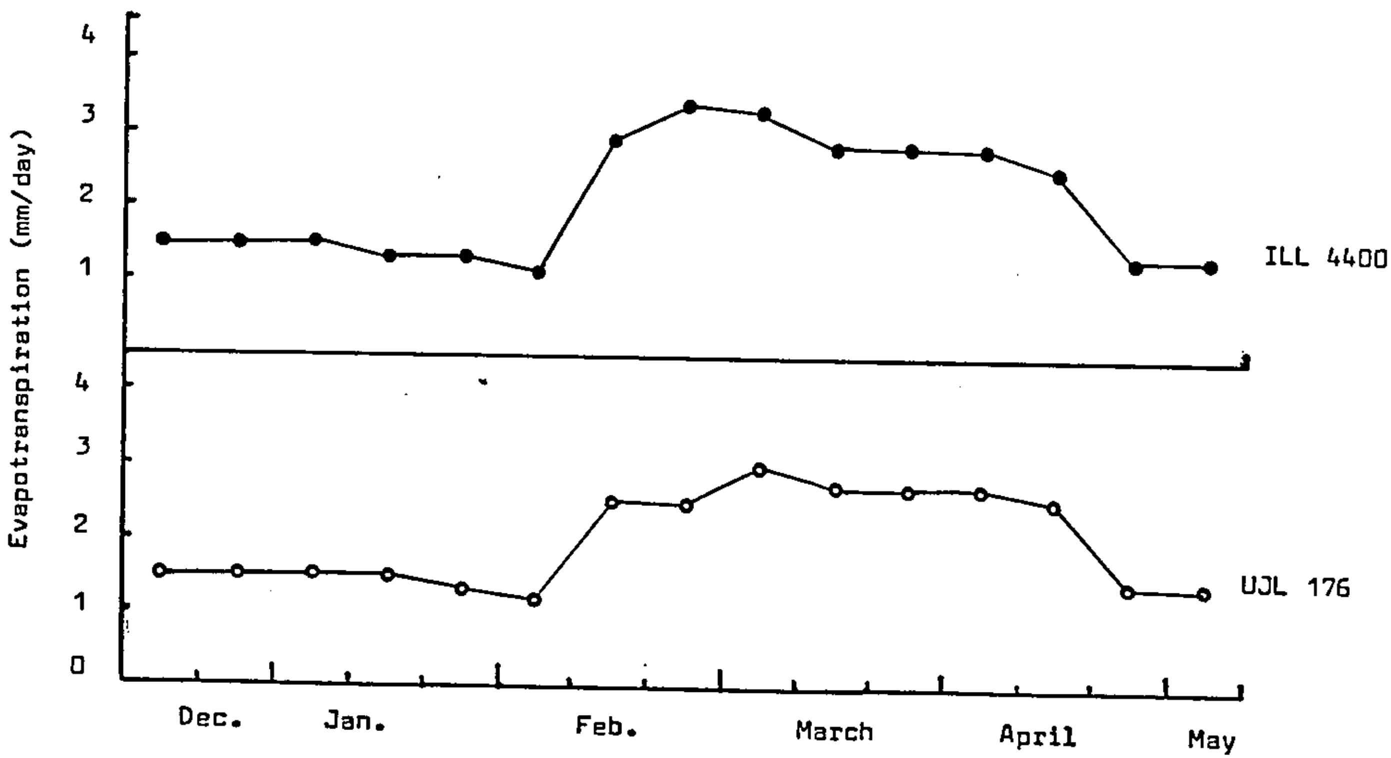

Figure 7. The variation of evapotranspiration rate for highest irrigated water level (W4) for two genotypes (UJL 176 and ILL 4400) grown in Ramtha during the 1984/85 growing season (The values are the average of 10-days interval).

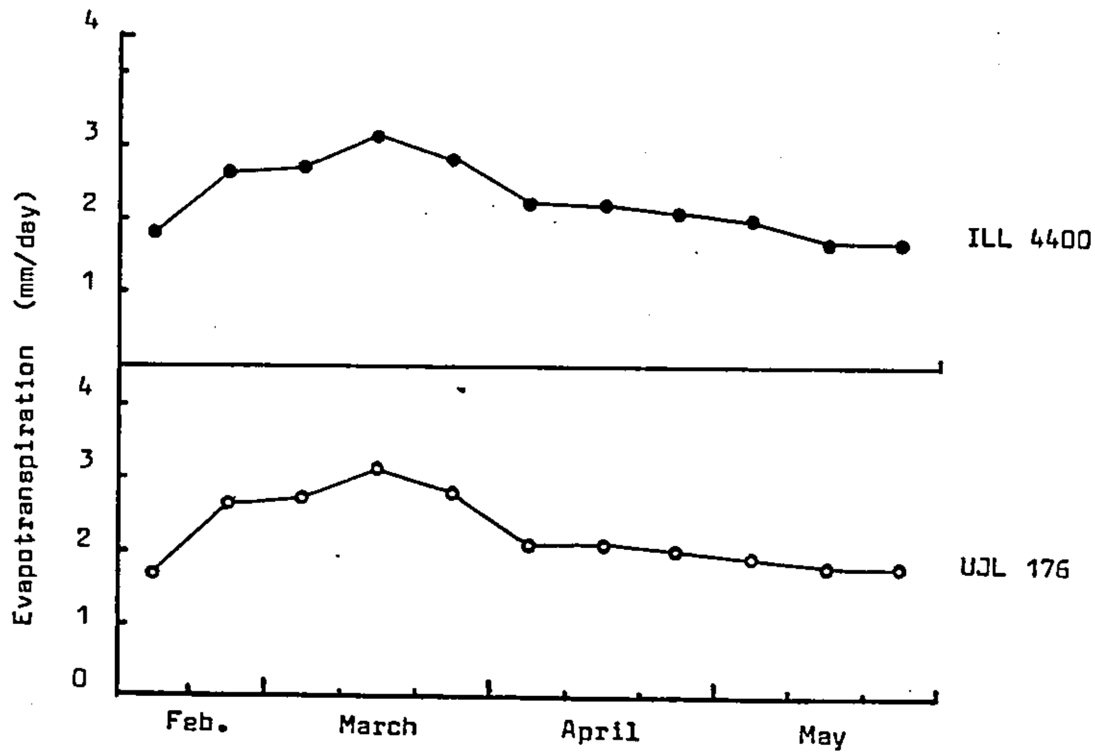

Figure 8. The variation of evapotranspiration rate for highest irrigated water level (W4) for two genotypes (UJL 176 and ILL 4400) grown in Ramtha during the 1985/86 growing season (The values are the average of 10-days interval).

of water were supplird in addition to rain; due to favorable conditions for ET (high termperatures, Figure 2 appendix C) in addition of more vegetative growth which use more water resulted in high rates of ET.

Evapotranspiration (ET) rates, presented in Figure 8, show reduction in their values for both genotypes from 60 days from emergence until maturity. During this period the amounts of rainfall were low, and amounts of applied water may not fit the full requirements of the plants. These results indicate that when the plant is subjected to stress, it will adapt its physiological system to control transpiration (Kramer, 1969).

4.1.2.2. Seasonal ET :

For all irrigation treatments, seasonal ET ranges from 234 to 295 mm and 236 to 302 mm for UJL 176 and ILL 4400, respectively, during 1984/85 season, whereas it ranged from 119 to 228 mm and from 122 to 231 mm for UJL 176 and ILL 4400, respectively, during 1985/86 season (Table 35). It increases with the increase of total amounts of water applied. The maximum ET occured under the highest water level (W4) where the lentil plants, received a total amounts of 311.3 and 295.2 mm during 1984/85 and 1985/86 seasons, respectively.'

The evapotranspiration values are comparable to some values reported by other workers where the environmental conditions are different. Hamoudi *et al*. (1983) found, in India, that seasonal ET for lentil ranged from 224.9 mm to 451.9 mm for maximum moisture stress and well-watered

Table 35. Evapotranspiration (ET) and water-use efficiency for biological yield (WUE 1) and grain yield (WUE 2) of two lentil genotypes grown in Ramtha under different levels of applied water during the 1984/85 and 1985/86 growing seasons.

Genotype	treatment	ET 1984/85	ET 1985/86	WUE 1 1984/85	WUE 1 1985/86	WUE 2 1984/85	WUE 2 1985/86
		mm	mm	$kg\ ha^{-1}$ mm	$kg\ ha^{-1}$ mm	$kg\ ha^{-1}$ mm	$kg\ ha^{-1}$ mm
UJL 176	W0	234	119	5.58	3.27	1.83	0.29
	W1	253	153	6.09	6.86	2.17	0.63
	W2	266	181	6.98	8.18	2.41	1.23
	W3	281	203	7.44	9.20	2.59	1.84
	W4	295	228	9.66	10.19	3.05	2.14
ILL 4400	W0	236	122	6.64	4.76	1.76	0.29
	W1	256	158	7.36	8.37	2.12	0.61
	W2	270	184	7.96	8.45	2.47	0.79
	W3	284	206	9.65	9.27	2.85	1.05
	W4	302	231	10.60	10.91	2.91	1.79

Soil treatments, respectively. Miller and Burke (1983), in USA, found that seasonal ET ranged from 220 mm to 270 mm for dry beans using sprinkler line source at the lowest and the highest rates of irrigation , respectively.

4.1.2.3. Relationship between ET and yield:

The seasonal water use (ET) and water use efficiency of the two genotypes studied under different soil moisture levels are presented in Table 35 .

The data suggested that the genotype ILL 4400 had higher water use when compared with UJL 176 genotype under all the water levels during both seasons. Comparing the water use of the driest treatment (W0) with the wettest treatment (W4), indicated that the range of water use was greatest for ILL 4400 genotype (ranged from 236 to 302 mm in 1984/85 season and from 122 to 231 mm in 1985/86 season) and lowest for UJL 176 gentoype (ranged from 234 to 295 mm in 1984/85 season, and from 119 to 228 mm in 1985/86 season, Table 35). This may be attributed to that UJL 176 genotype matured earlier than ILL 4400 during both seasons, ILL 4400 took 183 and 128 days from planting to maturity during 1984/85 and 1985/86 seasons, respectively; while UJL 176 genotype took 178 and 119 days for 1984/85 and 1985/86 seasons, respectively. In addition ILL 4400 is a large seeded lentil, with a more vigrous growth habit and larger leaf area, in comparison to UJL 176 which has a medium size seeds, and relatively smaller leaflets, contributing to the higher ET of ILL 4400, when compared with UJL 176 genotype.

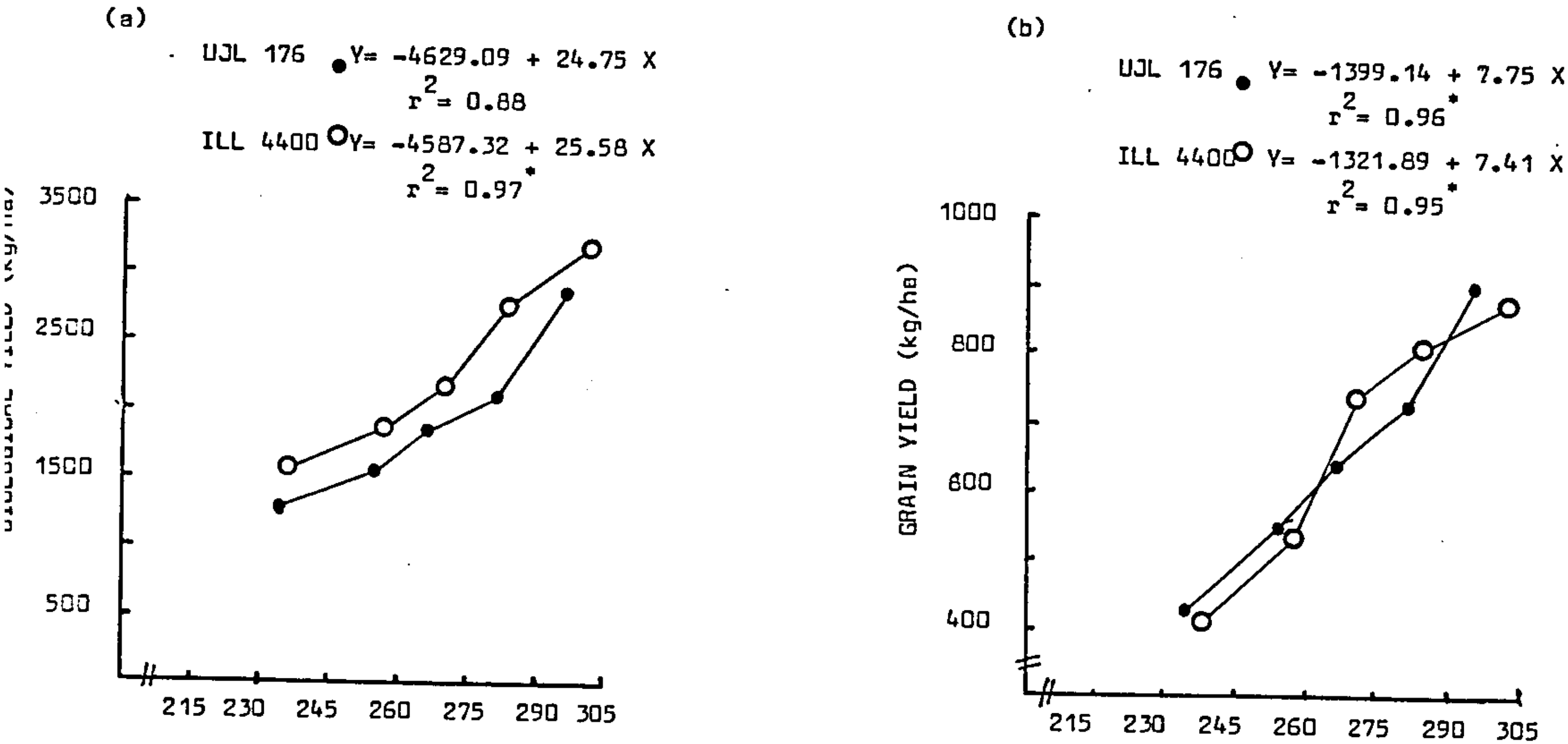

Figure 9. The relationship between evapotranspiration and (a) biological yield, and (b) grain yield for two lentil genotypes grown in Ramtha during the 1984/85 growing season.

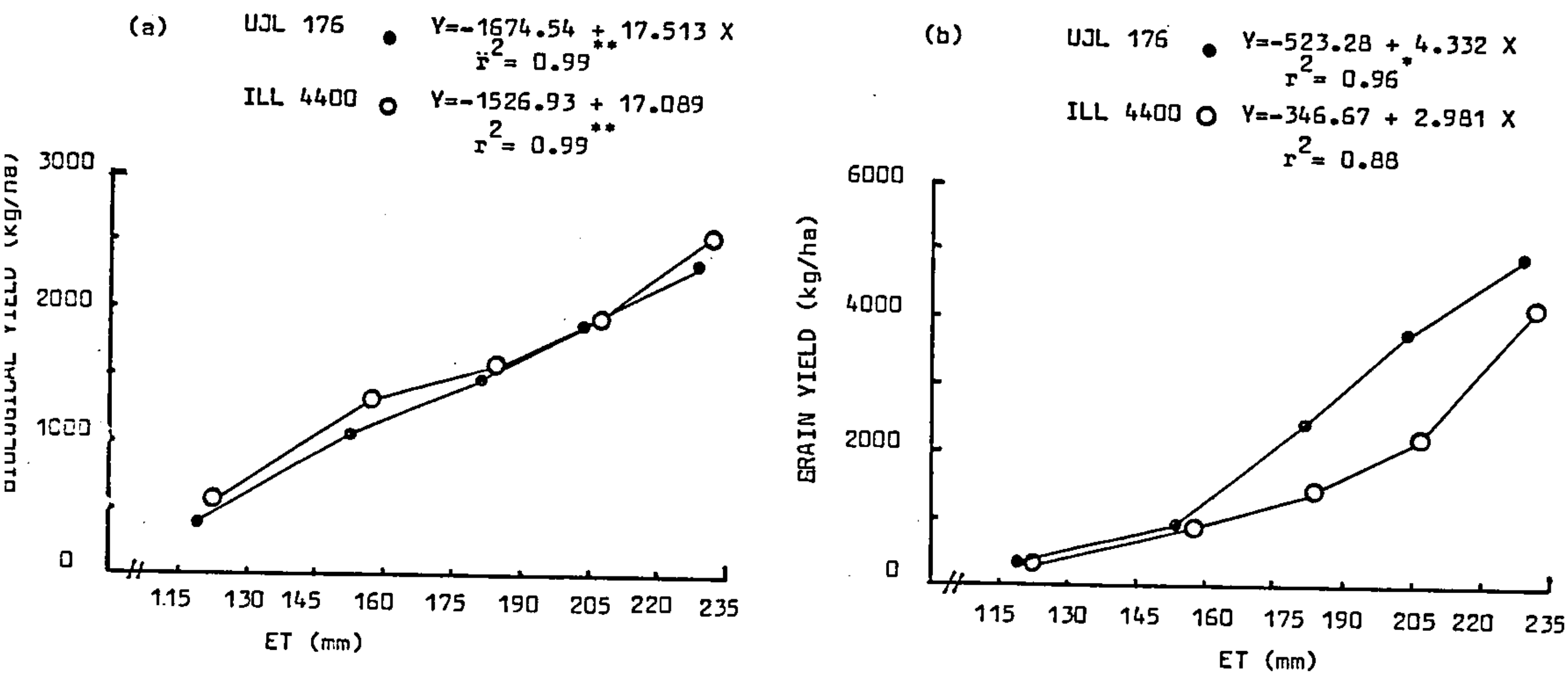

Figure 10. The relationship between evapotranspiration and (a) biological yield, and (b) grain yield for two lentil genotypes grown in Ramtha during 1985/86 growing season.

genotype . Similar results were reported by Pandey *et al.* (1984b) working on four grain legumes who found that longer period of crop growth leads to higher ET and finally more total dry matter produced.

The ability to produce superior grain yield under any given level of ET deficit is an important genotypic criterion. Genotype UJL 176 proved to be supeior to ILL 4400 because of higher grain productivity at all levels of ET (Table 35). This is probably due to that ILL 4400 genotype matured nearly 5 and 9 days later than UJL 176 during 1984/85 and 1985/86 seasons, respectively; thus encountered greater water stress. These results are in agreemement with those reported by Pandey *et al.*,(1984b) working on four grain legumes.

4.1.2.4. Water use efficiency (WUE):

Efficient utilization of limited water resources for crop production is essential for agriculture in water deficient regions. Therefore, WUE was calculated in lentils by dividing yield by total water used (ET).

Since the experiment in the first season was conducted under more favorable evaporative conditions (more soil moisture availability),therefore,total dry matter yield and consumptive water use values were largely different than that in the second season (Table 35).

Low yield (biological and grain) was produced under rainfed (W0) treatment and the highest under W4 treatment in both genotypes and for the two seasons. The genotype matured latest (ILL 4400) had the highest WUE1 and UJL 176, a relatively earlier maturing genotype in compared to first one, had the lowest WUE 1. This is attributed to higher total dry matter produced by ILL 4400 than UJL 176 and the reason behind that was explained earlier. However, UJL 176 had the highest WUE 2 at all treatments when compared to ILL 4400 genotype. The reason behind that was also explained earlier. Similar results were obtained by Lockerman et al. (1985) working on faba beans, and at ICARDA on lentils (ICARDA, 1983).

4.2. Stability Of Yield And Yield Components In Lentil:

The variation in the performance of lentils from season to season is quite high. This makes it essential to study the behavior of different improved varieties of lentil for their stability before release.

The analysis of variance for yield and yield components studied are presented in Table 36. Differences among genotypes and environments were highly significant for all characters studied.

The genotype X environment interaction was significant for all characters studied, indicating that genotypes differed in response to environmental stimuli. This satisfied the basic requirement for this study. Mean square was significant when tested against pooled error. Similar findings were obtained by many researchers working on lentils (Ahmad and Pandey, 1983, Singh and Mehra, 1976; Mehra and Pahuja 1979; and Sagar and Lal, 1980).

Table 36. Pooled analysis of variance for different characters.

Source of variation	d.f.	Mean Squares				
		Grain yield	Straw yield	Pods number/ plant	Seeds number/ pod	100-seed weight
Genotype (G)	9	50725.8**	141034.9*	49.0**	0.054**	7.62**
Environment(E)	7	1498564.9**	7580328.7**	714.7**	0.045**	2.40**
G X E	63	9670.1**	55926.0**	11.1**	0.003**	0.18**
Pooled error	216	18764.1	44255.2	15.68	0.008	0.35

*,** : Significant at 5 % and 1 % probability level, respectively.

Stability analysis as defined by Eberhart and Russell, (1986); is based on the three parameters; the mean ($\bar{x}$), regression coefficient (b) and deviation from regression (Sd^2). Their model suggest that a genotype with high mean, and with a regression coefficient not significantly different from unity and little or small deviation from regression would be the most desirable genotype.

Table 37 gives the average means over environments for the ten studied genotypes and two other parameters of stability, namely the regression coefficient (b) and variance of deviations (sd^2) from linear regression. However, results on yield and yield components for the 10 genotypes included in the study and for each season and location are presented in Tables 1 to 5 in appendix E .

4.2.1. <u>Grain yield</u>:

Genotypes UJL 405, UJL 176, 76 TA 66088 and UJL 289 gave greater grain yield than the population mean and proved to be useful materials. These four genotypes combined high mean performance with relatively unit linear response ($b > 1$) and low deviations from linearity. However, genotype 78 S-26013 gave higher yield than the population mean, but it was not stable genotype expressing large deviation from linearity. The genotypes ILL 4401, UJL 510, ILL 4400, Precoz and Winter lik-51 failed to give high mean values(Table 37).

Table 37. Stability parameters, based on Eberhart and Russell (1966), for yield and yield components in 10 lentil genotypes.

	Grain yield (kg ha^{-1})				Straw yield (kg ha^{-1})			
	$\bar{X}$	RK	b	sd^2	$\bar{X}$	RK	b	sd^2
UJL 405	567	1	1.31	2698.8	1275	1	1.211	28772.5
UJL 289	438	3	1.094	2875.8	1130	5	0.964	38131.8
76 TA 66088	434	4	1.083	2430.8	1051	8	0.894	11015.2
ILL 4401	313	10	0.762	2529.1	1060	7	0.878	16806.3
UJL 176	454	2	1.182	2932.9	1106	6	1.043	13881.9
UJL 510	329	8	0.804	15138.6	1039	9	0.796	85041.3
ILL 4400	370	6	0.875	2970.0	1188	4	1.093	31229.3
78 S-26013	420	5	1.200	7334.6	1193	3	1.355	95030.8
Precoz	318	9	0.892	631.9	812	10	0.823	8126.6
Winter lik-51	345	7	0.799	1162.6	1245	2	0.984	7030.9
General mean	399		1.00		1110		1.00	

Table 37. Continued.

Genotype	pods/plant				seeds/pod				100-seed weight (g)			
	$\bar{X}$	RK	b	sd^2	$\bar{X}$	RK	b	sd^2	$\bar{X}$	RK	b	sd^2
UJL 405	17.2	1	1.062	8.50	1.10	9	0.611	0.00	4.61	3	0.767	0.03
UJL 289	15.7	3	1.295	6.57	1.11	7	0.685	0.00	4.49	5	1.169	0.15
76 TA 66088	15.7	4	1.295	29.17	1.23	3	1.453	0.00	3.23	10	0.805	0.09
ILL 4401	13.4	7	0.962	4.92	1.32	1	1.891	0.00	3.50	8	0.591	0.09
UJL 176	16.2	2	1.224	2.42	1.10	10	0.559	0.00	4.21	6	1.028	0.11
UJL 510	9.2	10	0.622	0.32	1.13	6	0.957	0.00	5.98	1	2.065	0.13
ILL 4400	12.1	8	0.857	6.50	1.11	8	0.842	0.00	5.91	2	1.673	0.32
78 S-26013	15.4	5	1.095	3.53	1.14	5	0.585	0.00	3.43	9	0.763	0.07
Precoz	11.7	9	0.867	4.62	1.19	4	1.061	0.00	4.53	4	0.692	0.15
Winter lik-51	14.2	6	0.945	21.55	1.29	2	1.355	0.01	3.64	7	0.449	0.09
General mean	14.1		1.00		1.17		1.00		4.35		1.00	

The results indicated that the genotype UJL 405 was widely adapted, having the highest mean in the set (567 kg/ha), and a regression coefficient relatively near to unity (b $>$ 1) which indicated that the genotype possessed average stability. The variance due to deviations was also small. This genotype was followed by UJL 176 and UJL 289. These results appear to be consistant with that obtained with wheat described by Stroike and Johnson (1972), cultivars have an average or better response (large b) to more favorable conditions would be indicated as widely adapted cultivars.

It is important to indicate that the genotypes Precoz, UJL 510 and ILL 4401, the earliest maturing in the set, were the lowest yielding and they possessed a regression coefficient less than unity. Similar observations were reported by Singh and Mehra (1976) that the earliest maturing lentil genotypes were accompanied by low yields and small b values.

4.2.2. Straw yield:

The stability for straw yield was also investigated, because straw production is very important as animal feed in Jordan and the region.

Among the genotypes tested; UJL 405, Winter lik-51, ILL 4400 and UJL 289 gave higher straw yield than the population mean and proved to be useful material. These four genotypes combined high mean performance with unit linear response and low deviations from linearity. However genotype 78 S-26013 gave high straw yield, but it expressed large deviation from linearity.

The genotypes 76 TA 66088, ILL 4400, UJL 176, UJL 510 and Precoz gave low mean values (Table 37). The results indicate that UJL 405 was the highest yielding genotype (1275 kg/ha), with a regression coefficient relatively equal to unity (b $>$ 1) but expressed large deviation from linearity, so it cannot be considered as the most stable. However, Winter lik-51 ranked second in yield among the 10 genotypes (1245 kg/ha^{-1}), and had a regression coefficient relatively near to unity and with small variance, thus it is the most stable genotype. This genotype was followed by UJL 405, ILL 4400 and UJL 289. Singh and Mehra (1976) detected variations among tested varieties as result of variety by environment interaction.

4.2.3. <u>Number of pods per plant:</u>

Following the stability parameters used earlier, genotypes UJL 405, UJL 176, UJL 289, 76 TA 66088 and 78 S-26013 appeared to be promising as they combined high mean performance with unit linear response and relatively low deviation from linearity. Winter lik-51 however, gave a higher number of pods per plant than the population mean but with large deviation value from linearity and with, b $<$ 1 (Table 37).

The results indicated that UJL 405 was the most stable among tested genotypes, by having the highest mean in the set (17.2 pods/plant) and a regression coefficient equal to unity (b= 1.062), and small variance, followed by UJL 176 and UJL 289. On the other hand, 76 TA 66088 gave higher number of pods per plant than the population mean, however, it expressed had larger seeds than the population mean but expressed large deviation from linearity, so considered less stable genotypes for hunred seed weight.

Genotype UJL 176 had lower seed weight than the population mean but with unit linear response and low deviation from linearity so it considered to have average stability. Sagar and Lal (1980) reported that most of the variation among genotypes as result of genotype X environment interaction could be attributed to linear effects.

The study revealed that few genotypes possessed average stability for yield under the test conditions in Jordan. However, for long term strategy, it may be desirable to breed genotypes that are more responsive to environmental stimuli, as UJL 405 which show large b.

On the other hand, UJL 405, 76 TA 66088 and Winter lik-51 possess some yield components stable in response to environments, such as number of pods per plant, and number of seeds per pod, and therefore they should be involved in a breeding programme with selection exercised for responsiveness in the early segregating generations tested over a range of environments.

4.3. Effect Of Simulated Moisture Stress On Lentil Seed Germination:

4.3.1. Germination percentage:

Effects of moisture tension and genotype on germination percentage are presented in Table 38. Germination progressively decreased with increasing moisture tension. The highest average germination percentage under the

Table 38. Effect of moisture tension and lentil genotype on germination percentage, speed of germination, and root growth.

Tension/genotype	Germination %	Speed of germination	Root growth (cm plant day)
Tension[x]			
0.0 atm.	88.0 a*	4.71 a	0.51 a
5.0 atm.	46.7 b	1.41 b	0.08 b
10.0 atm.	34.7 c	0.69 c	0.06 c
15.0 atm.	8.0 d	0.09 d	0.00
Genotype +			
UJL 405	38.3 bc	1.70 cd	0.19 cd$
UJL 289	40.0 bc	1.72 b-d	0.19 cd
76 TA 66088	48.3 a-c	1.90 b	8.21 bc
ILL 4401	51.7 ab	1.84 bc	0.24 ab
UJL 176	43.3 a-c	1.63 d	0.21 bc
UJL 510	33.3 c	1.29 e	0.17 d
ILL 4400	45.0 a-c	1.66 cd	0.26 a
78 S-26013	46.7 a-c	1.66 cd	0.21 bc
Precoz	36.7 bc	1.31 e	0.21 bc
Winter lik-51	60.0 a	2.54 a	0.26 a

x Means of ten genotypes data.

* Means within each column followed by the same letter do not differ significantly from each other at the 5 % level of probability using DMRT.

\+ Means of four tension treatments (0, 5, 10 and 15 atm.).

$ For genotypes, root growth means are the mean of three tension treatments (0, 5, and 10 atm.).

four moisture tensions was for Winter lik-51 followed by ILL 4401 then 76 TA 66088 genotype. The genotypes UJL 510, Precoz and UJL 405 gave the lowest germination percentages. The differences in germination percentages of the genotypes was wider under the increased moisture tension than the low moisture tension. All genotypes were germinated under the 15.0 atm except for the UJL 289, UJL 510 and Precoz genotypes, however, the germination percentages for all genotypes were 8.0, 34.7, 46.7 and 88.0 % for 15.0, 10.0, 5.0 and 0.0 atm, respectively.

Significant interaction between genotype and osmotic potential was detected for germination percentage (Table 38). This suggests that genotypes differ with respect to osmotic potential. Germination percentage was significantly decreased for all genotypes with the change of moisture tension from 0.0 to 5.0 then to 10.0 and 15.0 atm. However, the genotype Winter lik-51 germinated significantly better than the other genotypes tested. These results are in agreement with the findings of several researchers working on different crops (Helmerick and Pfeifer, 1954; Ashraf and Abu-Shakra, 1978; and Jaradat, 1979), with respect to germination percentage that it decreased with increasing moisture tension.

4.3.2. Speed of germination:

Speed of germination expressed in terms of a Vigor index is animportant factor in crop seedling establishment (Helmerick and Pfeifer, 1954; and Parmer and Moore, 1968).

The high values indicate high speed of germination and the low values low speed of germination. Speed of germination was inversely related to the intensity of moisture stress. It was found that speed of germination decreased significantly with the increase of each five atmospheres in moisture tension. These results are in agreement with the findings of many workers (Helmerick and Pfeifer, 1954; Parmer and Moore, 1968; Read and Beaton, 1963; Ashraf and Abu-Shakra, 1978; and Jaradat, 1979).

Differences in speed of germination among genotypes were also significant. Winter lik-51 was the most vigrous among the 10 genotypes followed by 76 TA 66088, and ILL 4401; whereas UJL 510, Precoz and UJL 176 had lowest values of speed of germination among the genotypes tested. The high values for Winter lik-51, 76 TA 66088 and ILL 4401 indicate their vigorous stand even under high moisture tension as compared to the other genotypes tested. Genotypic differences with respect to speed of germination in several crops have been reported by many researchers (Evans and Stickler, 1961; Tadmor _et al_. 1969; Ashraf and Abu-Shakra, 1978; Jaradat, 1979; and Kazemi _et al_. 1977).

4.3.3. Rate of root growth:

It can be seen from the data presented in Table 38 that root growth was influenced by moisture tension and the response of the genotypes were also different. Significantly lower rates of root growth were found with the increase of each level of stress. These results are in agreement with those reported by several workers (Parmar and Moore, 1968; Wright, 1962; and Ashraf and Abu-Shakra, 1978).

Both genotypes ILL 4400 and Winter lik-51 showed significantly higher root growth rate than other genotypes tested. However, UJL 510 genotype showed the slowest root growth among the 10 genotypes tested. These results indicate a rapidly penetrating and deeper root system is essential for growing genotypes grown in semiarid areas to extract more moisture from the deep soil layers. Hurd (1968) found that rate of root growth and penetration of root varied from one cultivar of wheat to another.

4.3.4. Relative drought tolerance indices 1 and 2 (RDTI-1 and RDTI-2):

Results presented in Table 39 show that mean values over all genotype for RDTI-1 under 5.0, 10.0 and 15.0 tension are lower than the corresponding values of RDTI-2. Differences between over all genotype means were significant under 5.0, 10.0 and 15.0 atm. Furthermore, the mean values decreased with tension. Significant differences were also detected among the mean values of the genotypes under the different moisture stress treatments. Winter lik-51 and UJL 176 gave the highest values for both indices (Table 39). Moreover, the differences in the values of the indices of the genotypes were greater under the tension of 5.0 atm. and 10.0 atm. than under the tension 15.0 atm. Those differences among the genotypes may show real differences in the ability to tolerate drought at one of their growth stages. These indices are considered to be important indications of drought tolerance because they are largely independent of the physical characteristics

Table 39. Germination response of 10 lentil genotypes measured as (a) rate of germination (RDTI-1) and (b) total germination (RDTI-2) under induced osmotic stress.

Genotype	Mean relative drought tolerance index							
	RDTI-1				RDTI-2			
	Osmotic potential (atm.)				Osmotic potential (atm.)			
	5.0	10.0	15.0	Average	5.0	10.0	15.0	Average
UJL 405	0.25 c-e*	0.19 ab	0.03 a	0.16 ab	0.42 cd	0.42 ab	0.17 a	0.33 ab
UJL 289	0.25 c-e	0.03 d	0.00	0.09 d	0.45 bc	0.30 b	0.00	0.25 ab
76 TA 66088	0.28 b-d	0.06 ed	0.02 a	0.12 cd	0.47 bc	0.33 ab	0.13 a	0.31 ab
ILL 4401	0.28 b-d	0.07 cd	0.05 a	0.13 bc	0.53 bc	0.27 b	0.27 a	0.36 ab
UJL 176	0.29 b-d	0.25 a	0.03 a	0.19 a	0.50 a	0.50 ab	0.17 a	0.39 ab
UJL 510	0.20 e	0.09 c	0.00	0.10 d	0.32 d	0.23 b	0.00	0.18 b
ILL 4400	0.38 a	0.11 c	0.02 a	0.13 bc	0.63 bc	0.33 ab	0.08 a	0.35 ab
78 S-26013	0.29 b-d	0.25 a	0.03 a	0.19 a	0.55 b-c	0.28 b	0.13 a	0.32 ab
Precoz	0.32 b	0.19 ab	0.00	0.17 a	0.70 ab	0.47 ab	0.00	0.39 ab
Winter lik-51	0.31 bc	0.31 bc	0.01 a	0.18 a	0.73 a	0.60 a	0.07 a	0.47 a

* Means followed by the same letter within a column for the genotypes and for osmotic potential within an index do not differ significantly at the 5 % level of probability using DMRT.

of the seed and are also free of the inherent differences in germination percentage and the rate of germination (Bhatt, 1979).

4.3.5. Effect of moisture deficits on seedling growth:

Effect of moisture tension and genotype on length and fresh weight of shoots, root length and fresh weight are presented in Table 39. These characters were inversely affected when moisture was increased, so that there was no growth at 15 atm. tension.

There were significant differences between genotypes for all shoot and root characters. ILL 4400, ILL 4401 and Winter lik-51 genotypes had longer root systems as compared to the other genotypes tested. Similar trends were found for root fresh weight, where it decreased with increasing moisture tension, ILL 4400, Precoz and UJL 510 produced the highest root fresh weights.

Shoot length and fresh weight were reduced with increasing moisture stress for all genotypes tested. However, genotypes 78 S-26013, UJL 176 and 76 TA 66088 showed the highest values for shoot lengths, meanwhile, ILL 4400 and UJL 510 produced the highest shoot fresh weights.

Shoot length was less affected by increasing moisture stress than were the roots. This phenomenon was reported by Russell and Gingrich (1956) on corn. This suggests that the vegetative parts of the tested genotypes were able to grow, at different rates, under moisture tensions, which are inhibitory to root growth.

Table 40 . Effect of moisture tension and lentil genotype on shoot length, root length, shoot and root fresh weight/plant, and shoot: root weight ratio of 10 lentil genotypes subjected to different moisture stresses.

Tension/ genotype	Shoot length (cm)	Root length (cm)	Shoot fresh wt (mg)	Root fresh wt (mg)	S:R ratio
Tension[x]					
0.0 atm.	12.80 a*	7.18 a	1.14 a	0.45 a	2.5 a
5.0 atm.	1.90 b	1.07 b	0.18 b	0.12 b	1.5 b
10.0 atm.	1.10 c	0.81 c	0.13 c	0.11 c	1.2 c
15.0 atm.	0.00	0.00	0.00	0.00	0.0
Genotype+					
UJL 405	4.77 ef	2.59 cd	0.44 ef	0.18 e	2.4 ab
UJL 289	4.41 fg	2.66 b-d	0.46 d-f	2.10 b-d	2.1 cd
76 TA 66088	5.77 a-c	2.93 bc	0.46 d-f	0.20 c-e	2.3 ab
ILL 4401	5.49 b-d	3.38 a	0.43 f	0.21 b-e	2.0 cd
UJL 176	6.00 ab	2.99 b	0.47 c-e	0.22 b-d	2.1 cd
UJL 510	3.96 g	2.42 d	0.50 b	0.23 bc	2.2 bc
ILL 4400	5.33 c-e	3.69 a	0.60 a	0.27 a	2.2 bc
78's-26013	6.11 a	2.93 bc	0.49 b-d	0.19 de	2.6 a
Precoz	5.16 de	2.94 bc	0.49 b-d	0.24 b	2.0 cd
Winter lik-51	5.34 c-e	3.66 a	0.42 f	0.23 bc	1.8 d

x Means of 10 genotypes data.

* Means of each column, followed by the same letter do not differ significantly from each other at the 5 % level of probability using DMRT.

\+ Means of three tension treatments data (0, 5.0 and 10.0 atm.).

Because of the different responses of roots and shoots to the moisture tensions used, the shoot to root weight ratios were, consequently different and in general were reduced as moisture tension increased (Table 40). Shoot to root ratios were reported to vary with changes in environmental conditions (Sandhu and Laude, 1958). The genotypes Winter lik-51, Precoz, and ILL 4401 were characterized by lower S:R ratios when compared with other genotypes tested. A reduced S:R ratio was reported to be a sign for drought tolerance (Sandhu and Laude, 1958; and Andrew and Solunki, 1966).

The results of this study indicate that both moisture tension and genotype have shown effects on the studied parameters. The genotypes reacted differently to stress, suggesting genetic variation among genotypes which can be utilized to produce lentils adapted to arid and semiarid regions. Germination criteria, like speed of germination, and root growth can be used for selecting drought resistant genotypes.

It can be concluded that Winter lik-51 is the most tolerant to D-mannitol induced osmotic stress.

4.4. Comparison between yield in the field trials and some characters studied in the laboratory test:

The comparisons between grain yield and straw yield for the ten tested genotypes grown in Ramtha location under supplementary irrigation for the two seasons are presented in Table 41. The germination percentage and the speed of germination for the ten genotype tested under laboratory conditions are also presented in Table 41.

From this table it can be seen that genotype Winter lik-51 gave the highest grain yield in 1984/85 season, followed by genotype ILL 4401. In 1985/86 season, genotype Winter lik-51, was the second in ranking.

In respect of germination percentage and speed of germination,the genotype Winter lik-51 was the first, followed by ILL 4401. The genotypes Precoz and UJL 510 produced the lowest grain yield in both seasons and ranked 9 and 10 among the genotypes, respectively. These two genotypes were also the lowest in ranking in respect to germination percentage and speed of germination. This indicates that the relationship between the germination percentage and speed of germination, and grain yield is stable. Therefore the former two characters can be used for selecting drought resistant genotypes.

However, when the correlation coefficients were calculated, using spearman's rank correlation, between grain yield in both seasons and speed of germination and germination percentage for the ten genotypes. The results indicated that grain yield was significantly correlated with germination percentage during 1984/85 growing season only ($r= 0.733$, $P < 0.05$).

Straw yield was also positively related to germination percentage and speed of germination. The genotype Winter lik-51 ranked the first and second among tested genotypes for straw yield in 1984/85 and 1985/86 seasons, respectively. This genotype was followed by 78 S-26013 and UJL 405. The genotypes UJL 510 and Precoz produced the lowest in respect to straw yield and ranked 9 and 10 among the genotypes, respectively. This indicates that the relationship between the germination percentage and speed of germination, and straw yield is also stable.

Since Winter lik-51 genotype is the most tolerant to D-mannitol induced osmotic stress, and proved to be superior in grain yield in the field experiments, it can be concluded that Winter lik-51 is the most drought tolerant among the tested genotypes. It also can be concluded that screening with D-mannitol could be a potentially valuable method of initial screening for drought tolerance.

SUMMARY

The present work was conducted to study the effect of simulated drought conditions on yield, nodulation and other agronomic characteristics of lentil. Ten lentil genotypes were evaluated, namely, UJL 405, UJL 289, 76 TA 66088, ILL 4401, UJL 176, UJL 510, ILL 4400, 78 S-26013, Precoz and Winter lik-51. The study was carried out using three different methods during 1984/85 and 1985/86 growing seasons.

In the first method, sprinkler line source was used to induce different moisture levels in Ramtha research station. A randomized complete block desigh with four replications was used, however, split-plot design was used in statistical analysis; genotypes as main plot and water levels as subplot. The following characteristics were studied: grain yield, straw yield, harvest index, plant height, number of pods per plant, number of seeds per pod, hundred seed weight, number of primary branches per plant, number of secondary branches per plant and numbdr of nodules per plant.

In the second method, the genotypes were evaluated for their yield and yield components stability at three locations, namely, Ramtha, Jubeiha and Maru, using two dates of planting, the first date early in the season and the second 6 to 8 weeks later. A randomized complete block design with four replications was used. Grain yield, straw yield, number of pods per plant, number of seeds per pod and hundred seed weight were studied.

In the third method, same genotypes were tested in the laboratory for seed germination under simulated drought conditions, using D-mannitol to induce moisture deficits. Four moisture tensions were used, namely, 0, 5, 10 and 15 atm. Split-plot design with three replications was used in this experiment; moisture tensions as main plot and genotypes as subplot. In this experiment, the following were studied: germination percentage, speed of germination, root growth, relative drought tolerance indices (RDTI-1 and 2), shoot length and fresh weight and root length and fresh weight.

The results indicated that moisture stress significantly affected the grain yield of lentils. An increase in grain yield were obtained with increasing moisture level, during both seasons. However, genotypes Winter lik-51, UJL 405 and 76 TA 66088 gave higher yields than other tested genotypes; and these genotypes showed the least reduction percentages in response to increasing moisture stress level from the lowest (W4) to the highest (W0), indicating the ability of these genotypes to resist drought over the other tested genotypes. Moreover, Winter lik-51 showed the greatest yield response to applied water in both seasons.

Grain yield was positively and significantly correlated with the amount of water applied plus rainfall for all the genotypes tested; coefficient of determination (r^2) ranged from 0.79 to 0.92 for both growing seasons. However, Winter lik-51, UJL 289 and 78 S-26013 had the greatest yield response to applied water (b= 7.964, 7.532 and 7.367 , respectively) during 1984/85 season. On the other hand, genotypes UJL 405, ILL 4401 and Winter lik-51 had the greatest yield response (b= 4.758, 4.492 and 4.449, respectively) during 1985/86 season.

Moisture level also, affected significantly and positively some of the plant characters; as moisture level increased, the number of pods per plant, number of seeds per pod, number of primary branches per plant, number of secondary branches per plant, plant height and the number of nodules per plant increased.

The data strongly suggested that the genotype ILL 4400 had higher water use when compared with UJL 176 genotype under all the water levels during both seasons. However, water use efficiency was higher for biological yield in ILL 4400 than UJL 176, whereas UJL 176 had higher water use efficiency for grain yield druing both seasons.

The stability parameters suggested by Eberhart and Russell (1966), the performance mean ($\bar{x}$), regression coefficient (b), and deviation from regression (sd^2), was applied to the data of the second experiment. The results indicated that the genotype UJL 405 was widely adapted, having the highest mean grain yield in the tested genotypes (567 kg ha^{-1}), and a regression coefficient relatively near to unity ($b > 1$) which indicated that it possessed average stability. The variance due to deviations from regression was also small. This genotype was followed by UJL 176 and UJL 289. However, genotypes Precoz, UJL 510 and ILL 4401, the earliest maturing in the set showed less stability; they gave the lowest yields and had a regression coefficients less than unity.

On the other hand, UJL 405, 76 TA 66088 and Winter lik-51 possess some yield components responsive to environments such as number of pods per plant and number of seeds per pod.

Results of the laboratory test indicated that both moisture tension and genotype have shown effects on the studied parameters. Increasing moisture tension has caused significant reductions in the germination percentage, speed of germination, root growth rate, shoot length and fresh weight and root length and fresh weight. The genotypes differed in their germination in response to different moisture tensions. The genotypes Winter lik-51, ILL 4401 and 76 TA 66088 were superior in drought tolerance than other tested genotypes.

Based on field observations and the induced osmotic stress by D-mannitol, Winter lik-51 proved to be the most drought tolerant genotype.

الملخص باللغة العربية

تأثير ظروف الجفاف المحدثة على عشرة اصناف من العدس (Lens culinaris Medic.)

تعتمد زراعة العدس في منطقة البحر الابيض المتوسط ومنها الاردن على ظروف الزراعة المطرية، حيث ان احدى المشاكل الرئيسية التي تواجه زراعة العدس في الاردن هي ظروف الجفاف السائده وخصوصا في الجزء الاخير من الموسم، لذلك فان اختيار الاصناف التي تقاوم او تتحمل الجفاف هي احدى الاهداف الرئيسية لمزراعي العدس والباحثين في المنطقة.

الهدف من هذه الدراسة هو اختبار عشرة اصناف من العدس لمعرفة مدى تحملها لظروف الجفاف واختيار الافضل من حيث الانتاجية العالية وثباتية انتاجيتها تحت الظروف البيئية المختلفة في مناطق مختلفه من الاردن.

اجريت الدراسة خلال موسمين زراعيين ١٩٨٤/١٩٨٥ و ١٩٨٥/١٩٨٦ وقسمت الى ثلاثة اجزاء مختلفة. في الجزء الاول، اختبرت الاصناف العشرة تحت خمسة مستويات من الري في محطة الرمثا الزراعية، وتم تزويد التجربة بالري عند توقف نزول المطر لفترة طويلة. استعمل تصميم القطع العشوائية الكاملة، في اربع مكررات لهذه التجربة وتم دراسة الصفات التالية: وزن الحب، وزن القش، دليل الحصاد، طول النبات، عدد الافرع الرئيسية، عدد الافرع الثانوية، عدد العقد البكتيرية، عدد القرون وكل ذلك لكل نبات بالاضافة الى عدد البذور لكل قرن ووزن مئة حبة.

وفي الجزء الثاني من الدراسة اختبرت نفس الاصناف لمعرفة مدى ثباتية الانتاج ومكوناته تحت ظروف ثلاث محطات في الاردن وهي الجبيهه، الرمثا ومرو حيث زرعت في موعدين، الاول في بداية الموسم، والثاني متأخرا عنه بفترة ٦-٨ اسابيع.

اما في الجزء الثالث من هذه الدراسة فقد تم اختبار نفس الاصناف في المختبر حيث انبتت بذور العشرة اصناف تحت مستويات مختلفة من الشد الرطوبي احدثت باستعمال (D-mannitol).

دلت النتائج ان الاصناف UJL 405, Winter lik-51,76 TA 66088 أثبتت مقدرتها على مقاومة الجفاف، حيث اظهرت اقل تأثرا بزيادة مستوى الجفاف من ادنى مستوى له الى اعلى مستوى . كما دلت النتائج ان الصنف ILL 4400 كان اكثر كفاءة في استعمال المياه لانتاج محصول اكبر من الحب بالمقارنة مع الصنف ILL 4400

كما بينت النتائج ان الصنف UJL 405 كان من اكثر الاصناف تأقلما مع الظروف البيئية في محطات الجبيهة، الرمثا ومرو. وانه اكثر ثباتية في الانتاج بالمقارنة مع الاصناف الاخرى، حيث اعطى اعلى انتاج من الحب.

هذا وكانت نتائج المختبر متوافقه بصورة عامة مع نتائج الحقل حيث اثبتت ان الصنف Winter lik-51 هو اكثر الاصناف تحملا لظروف الجفاف في المختبر وكان قد اعطى اعلى انتاجا من الحب من الاصناف الاخرى والاكثر مقاومة للجفاف تحت ظروف تجربة الري في محطة الرمثا الزراعية.

CONCLUSTIONS AND RECOMMENDATIONS

From the present study, the following can be concluded:

1. Moisture stress is one of the most important factors affecting , lentil yield. Increased moisture level was found to increased grain yield, straw yield, plant height and most of the agronomical characters studied. However, grain yield could be improved either by improving number of branches per plant and/or the number of pods per plant.

2. Genotypes reacted differently to stress, suggesting genetic variation among genotypes which can be utilized to produce adapted varieties to arid and semi-arid regions. However, Winter like-51 and ILL 4401 produced the highest grain yield during both growing seasons.

3. The least reduction percentages with increased moisture stress level from the lowest (W4) to the highest (W0) in the grain yield were recorded with Winter lik-51, 76 TA 66088 and UJL 405 genotypes during both seasons. Indicating the ability of these genotypes to resist drought over other tested genotypes.

4. The data suggested that genotype UJL 176 was more productive and use water more efficiently for grain yield production, as compared to ILL 4400.

5. For long term strategy, it may be desirable to breed genotypes that are more responsive to environmental stimuli, as UJL 405 which shows the most stable response among the tested genotypes.

6. Genotypes UJL 405, 76 TA 66088 and Winter lik -51 possess some yield components stable in response to environments, such as number of pods per plant and number of seeds per pod . Therefore they should be involved in a breeding programme with selection exercised for responsiveness in the early segregating generations tested over a range of environments.

7. Since Winter lik-51 genotype is the most tolerant to D-mannitol induced osmotic stress, and proved to be superior in its grain yield in the field experiments, we can conclude that Winter lik-51 is the most drought tolerant among the tested genotypes. It can be also concluded that screening with D-mannitol could be a potentially valuable method of initial screening for drought tolerance.

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Table 1. Some agronomic characters of the 10 lentil genotypes used in the study.

Genotype	Cotyledon colour	Seed coat colour	Seed size*	Maturity time
UJL 405	Yellow	Greenish yellow	Small	Late
UJL 289	Yellow	Greenish yellow	Large	Intermediate
76 TA 66088	Red	Red with small black spots	Small	Intermediate
ILL 4401	Red	Brownish red	Small	Early
UJL 176	Yellow	Greenish yellow	Small	Intermediate
UJL 510	Yellow	Greenish yellow	Large	Early
ILL 4400	Yellow	Greenish yellow	Large	Late
78 S-26013	Red	Red	Small	Intermediate
Precoz	Yellow	Greenish yellow	Large	Early
Winter lik-51	Red	Brownish red	Small	Late

* Large $\geq$ 6 mm, Small $\leq$ 5 mm, in their diameter.

Table 1. Chemical and physical properties of D-mannitol are the following:

1.	Chemical formula:	$CH_2OH\ (CHOH)_4\ CH_2OH$
2.	Molecular weight =	182.17 g / mole.
3.	Specific rotation $(\alpha)^{25}$ D:	$+ 23.3^o$ to $+ 24.3^o$
4.	Insoluble matter	0.010 %.
5.	Loss on drying at 105 c^o	0.050 %.
6.	Residue after ignition	0.010 %.
7.	Reducing sugar	Pass test
8.	Heavy metals (as Pb)	5 ppm.
9.	Titratable acid	0.0008 meq/g.

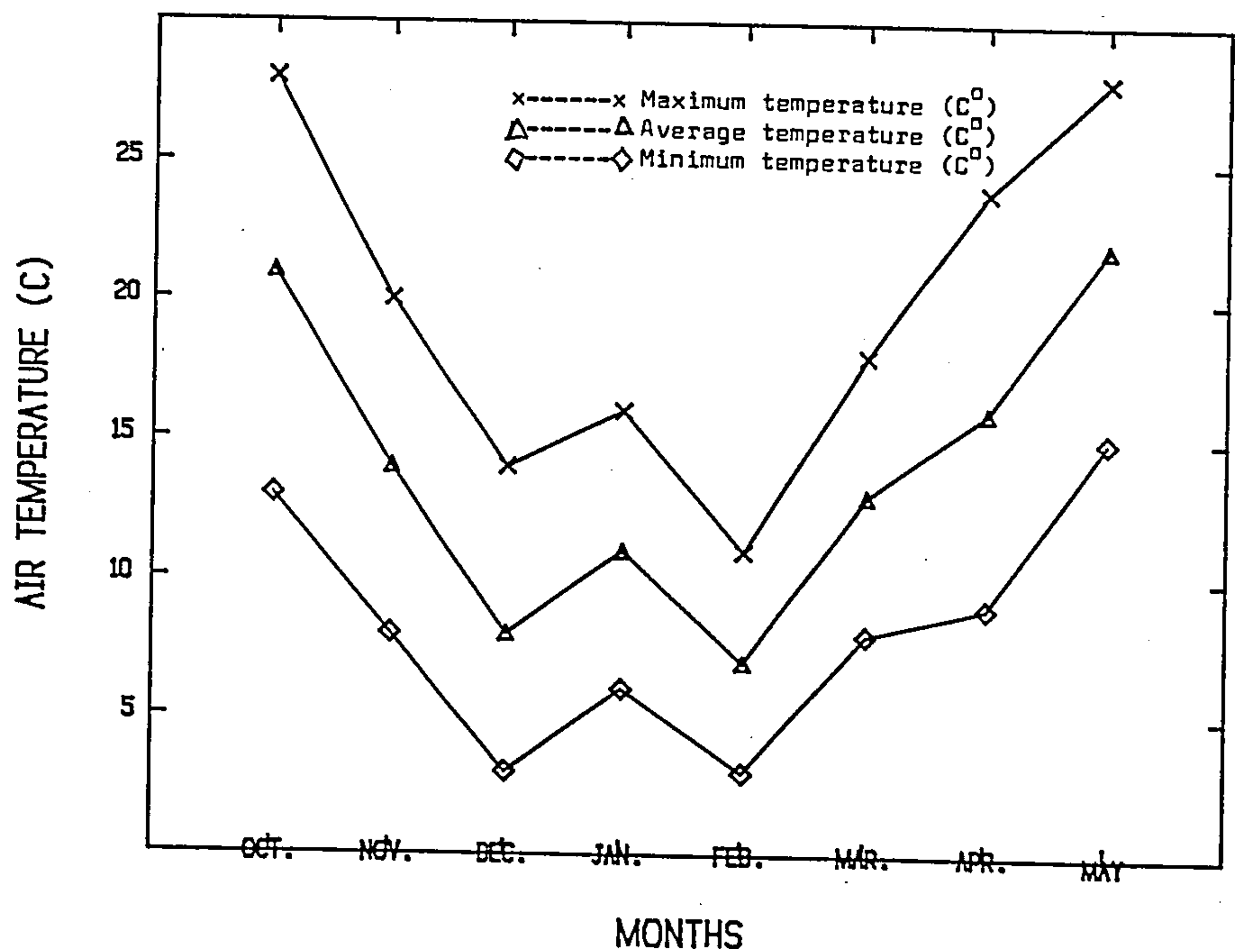

Figure 1. Maximum, minimum and average air temperatures during the 1984/85 growing season in Ramtha/Jordan.

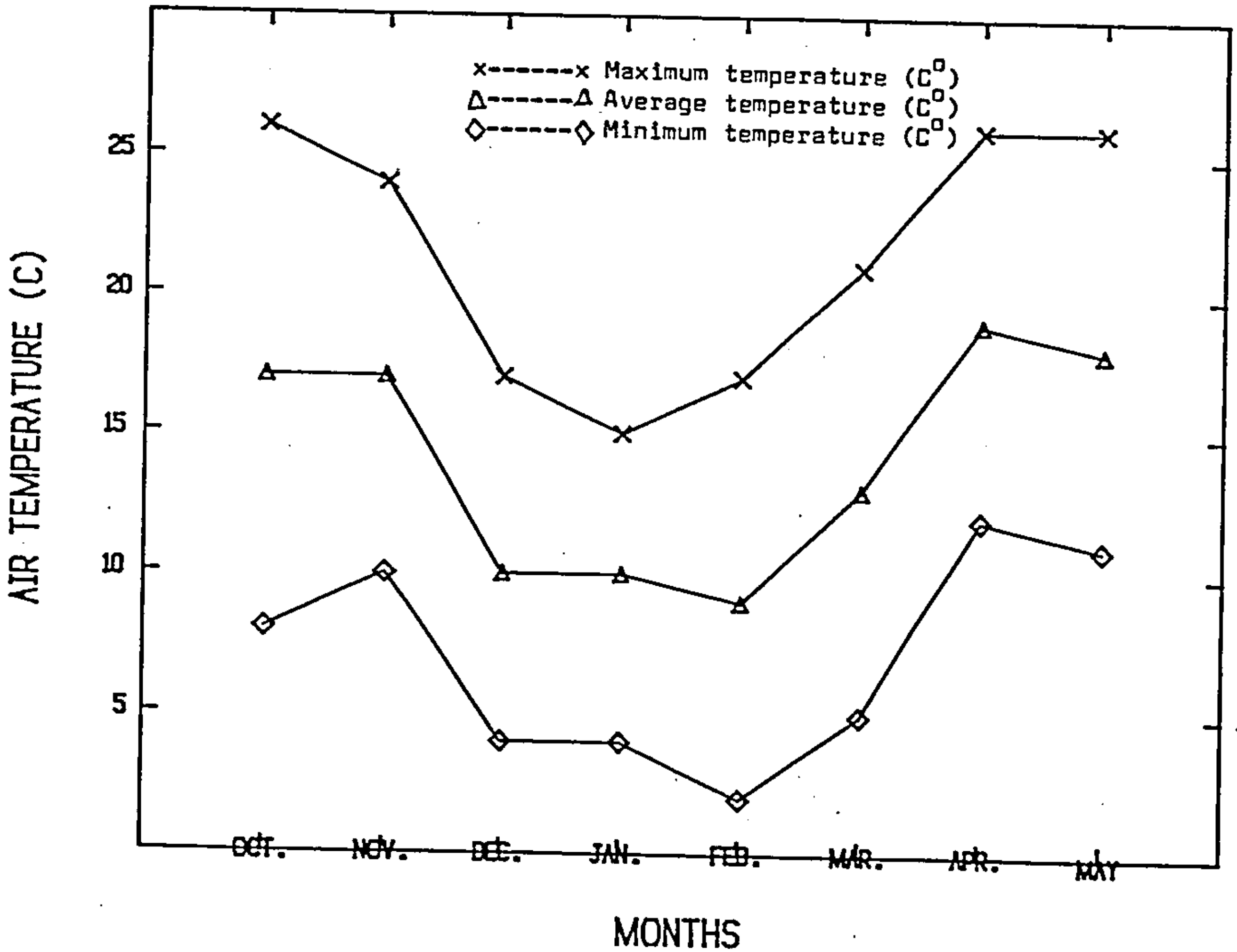

Figure 2. Maximum, minimum and average air temperatures during the 1985/86 growing season in Ramtha/Jordan.

Table 1. Analysis of variance for grain yield.

Source of variation	D.F.	M.S.		F.	
		1984/85	1985/86	1984/85	1985/86
Blocks	3	19159.86	9765.79	4.86**	1.45 NS
Genotypes	9	187351.85	109399.47	47.54**	16.29**
Error (a)	27	3941.26	6715.56		
Water levels	4	1176972.21	1317991.73	775.46**	709.80**
Genotypes X Water levels	36	6674.06	11192.31	4.40**	6.03**
Error (b)	120	1517.76	1856.84		

**: The F value is significant at the 1 % probability level.

NS= Not significant.

Table 2. Analysis of variance for straw yield.

Source of variation	D.F.	M.S. 1984/85	M.S. 1985/86	F. 1984/85	F. 1985/86
Blocks	3	46513.01	48984.66	2.47 NS	1.06 NS
Genotypes	9	1551363.31	623107.61	82.29**	13.47**
Error (a)	27	18851.91	46258.20		
Water levels	4	5257905.71	13148484.19	521.52**	622.54**
Genotypes X Water levels	36	62085.41	56549.53	6.16**	2.68**
Error (b)	120	10081.79	21120.00		

**: The F value is significant at the 1 % probability level.

NS= Not significant.

Table 4. Analysis of variance for plant height (cm).

Aource of variation	D.F.	M.S.		F.	
		1984/85	1985/86	1984/85	1985/86
Blocks	2	23.71	14.447	8.81**	5.13*
Genotypes	9	35.62	11.070	13.23**	3.93*
Error (a)	27	2.69	2.815		
Water levels	4	219.63	450.566	172.73**	328.98**
Genotypes X Water levels	36	2.03	2.018	1.59*	1.47 NS
Error (b)	120	1.27	1.370		

*,**: The F value is significant at the 5 % and 1 % probability level, respectively.

NS = Not significant.

Table 5. Analysis of variance for number of pods per plant.

Source of variation	D.F.	M.S.		F.	
		1984/85	1985/86	1984/85	1985/86
Blocks	3	19.62	6.628	2.94*	2.34 NS
Genotypes	9	319.68	78.123	47.96**	27.58**
Error (a)	27	6.67	2.833		
Water levels	4	1019.81	2109.341	401.81**	1094.63**
Genotypes X Water levels	36	11.92	11.664	4.70**	6.05**
Error (b)	120	2.54	1.927		

*,**: The F value is significant at the 5 % and 1 % probability level, respectively.

NS = Not significant.

Table 6. Analysis of variance for Number of seeds per pod.

Source of variation	D.F.	M.S. 1984/85	M.S. 1985/86	F. 1984/85	F. 1985/86
Blocks	3	0.018	0.007	2.09 NS	2.89 NS
Genotypes	9	0.218	0.195	25.76**	79.22**
Error (a)	27	0.008	0.002		
Water levels	4	0.005	0.091	1.56 NS	25.59**
Genotypes X water levels	36	0.003	0.006	0.100 NS	1.80**
Error (b)	120	0.003	0.004		

**: The F value is significant at the 1 % probability level.

NS = Not significant.

Table 7. Analysis of variance for 100-seed weight.

Source of variation	D.F.	M.S.		F.	
		1984/85	1985/86	1984/85	1985/86
Blocks	3	1.166	0.522	2.40 NS	5.74**
Genotypes	9	29.435	32.637	60.65**	358.69**
Error (a)	27	0.485	0.091		
Water levels	4	2.790	0.418	34.72**	3.66**
Genotypes X Water levels	36	0.142	0.256	1.76*	2.24**
Error (b)	120	0.080	0.114		

*,**: The F value is significant at the 5 % and 1 % probability level, respectively.

NS = Not significant.

Table 8. Analysis of variance for Number of primary branches/plant.

Source of variation	D.F.	M.S.		F.	
		1984/85	1985/86	1984/85	1985/86
Blocks	3	0.029	0.134	1.30 NS	7.10**
Genotypes	9	0.266	0.166	12.09**	8.77**
Error (a)	27	0.022	0.019		
Water levels	4	1.267	4.512	123.79**	158.88**
Genotypes X Water levels	36	0.015	0.086	1.46 NS	3.02**
Error (b)	120	0.010	0.028		

**: The F value is significant at the 1 % probability level.

NS= Not significant.

Table 9. Analysis of variance for secondary branches per plant.

Source of variation	D.F.	M.S. 1984/85	M.S. 1985/86	F. 1984/85	F. 1985/86
Blocks	3	2.347	5.036	1.95 NS	0.65 NS
Genotypes	9	12.063	7.246	10.01**	0.93 NS
Error (a)	27	1.205	7.774		
Water levels	4	104.368	308.914	123.46**	44.84**
Genotypes X Water levels	36	1.892	8.268	2.24**	1.20 NS
Error (b)	120	0.845	6.890		

**: The F value is significant at the 1 % probability level.

NS= Not significant.

Table 10. Analysis of variance for number of Nodules per plant.

Source of variation	D.F.	M.S.		F.	
		1984/85	1985/86	1984/85	1985/86
Blocks	2	9.031	20.356	1.44 NS	3.85*
Genotypes	9	48.302	7.826	7.72**	1.48 NS
Error (a)	27	6.259	5.293		
Water levels	4	1320.436	1637.609	321.53**	420.95**
Genotypes X Water levels	36	5.813	7.308	1.42 NS	1.88**
Error (b)	120	4.107	3.890		

*,**: The F value is significant at the 5 % and 1 % probability level, respectively.

NS = Not significant.

Table 1. Effect of planting date on grain yield (kg ha^{-1}) of 10 lentil genotypes grown in three locations during 1984/85 and 1985/86 growing seasons.

Genotype	1984/85					1985/86		
	Jubeiha		Ramtha	Maru		Jubeiha		Ramtha
	D_1	D_2	D_1	D_1	D_2	D_1	D_2	D_1
UJL 405	1014	229	454	263	37	1581	670	290
UJL 289	726	130	308	64	64	1324	559	250
76 TA 66088	784	56	346	209	71	1286	519	197
ILL 4401	455	113	279	79	50	964	361	202
UJL 176	749	184	374	95	87	1440	523	178
UJL 510	804	95	102	90	36	861	399	248
ILL 4400	703	102	236	141	77	1012	230	160
78 S-26013	624	85	272	149	83	1474	521	152
Precoz	605	83	221	43	50	1020	410	112
Winter lik-51	547	91	257	134	66	998	416	250

Table 2. Effect of planting date on straw yield (kg ha^{-1}) of 10 lentil genotypes grown in three locations during 1984/85 and 1985/86 growing seasons.

Genotype	1984/85					1985/86		
	Jubeiha		Ramtha	Maru		Jubeiha		Ramtha
	D_1	D_2	D_1	D_1	D_2	D_1	D_2	D_1
UJL 405	2028	738	663	645	288	3631	1932	552
UJL 289	199.33	616	717	495	354	2630	1904	462
76 TA 66088	1474	465	654	633	554	2611	1629	289
ILL 4401	1553	620	954	504	344	2557	1639	406
UJL 176	1451	795	676	470	322	2980	1755	395
UJL 510	1638	572	365	543	427	2048	2064	649
ILL 4400	1397	644	714	601	248	2982	2585	396
78 S-26013	1218	573	637	651	384	3873	1961	248
Precoz	1099	430	412	220	359	2199	1507	270
Winter lik-51	1561	668	960	712	647	2911	1899	601

Table 3. Effect of planting date on number of pods per plant of 10 lentil genotypes grown in three locations during 1984/85 and 1985/86 growing seasons.

Genotype	1984/85					1985/86		
	Jubeiha		Ramtha	Maru		Jubeiha		Ramtha
	D_1	D_2	D_1	D_1	D_2	D_1	D_2	D_1
UJL 405	30.8	14.6	22.5	13.5	4.0	27.7	11.1	8.7
UJL 289	33.3	7.6	16.5	10.8	5.1	25.4	11.9	8.2
76 TA 66088	41.6	4.6	17.6	16.9	6.7	20.9	9.5	7.4
ILL 4401	26.9	8.8	21.2	10.0	4.9	21.1	8.0	5.9
UJL 176	35.2	11.5	20.6	11.3	6.3	26.9	11.6	6.0
UJL 510	17.9	6.1	11.3	7.2	3.2	15.9	6.5	5.5
ILL 4400	24.4	7.1	11.6	8.7	4.0	21.9	14.2	4.9
78 S-26013	29.2	7.5	19.4	11.4	4.7	28.8	8.4	9.6
Precoz	22.4	7.0	18.3	8.0	3.1	17.1	6.5	7.2
Winter lik-51	22.7	6.5	17.8	10.0	3.7	18.4	9.3	5.5

Table 4. Effect of planting date on number of seeds per pod of 10 lentil genotypes grown in three locations during 1984/85 and 1985/86 growing seasons.

Genotype	1984/85					1985/86		
	Jubeiha		Ramtha	Maru		Jubeiha		Ramtha
	D_1	D_2	D_1	D_1	D_2	D_1	D_2	D_1
UJL 405	1.16	1.16	1.06	1.05	1.10	1.07	1.16	1.03
UJL 289	1.14	1.14	1.08	1.03	1.11	1.12	1.19	1.02
76 TA 66088	1.30	1.23	1.05	1.15	1.22	1.35	1.36	1.19
ILL 4401	1.41	1.32	1.08	1.31	1.26	1.47	1.50	1.24
UJL 176	1.13	1.18	1.07	1.08	1.06	1.08	1.16	1.03
UJL 510	1.21	1.25	1.04	1.05	1.09	1.12	1.19	1.10
ILL 4400	1.23	1.10	1.02	1.07	1.15	1.18	1.12	1.03
78 S-26013	1.18	1.16	1.07	1.14	1.12	1.22	1.14	1.10
Precoz	1.124	1.34	1.05	1.16	1.16	1.19	1.22	1.13
Winter lik-51	1.32	1.29	1.06	1.29	1.20	1.46	1.35	1.31

Table 5. Effect of planting date on 100-seed weight (g)/ of 10 lentil genotypes grown in three locations during 1984/85 and 1985/86 growing seasons.

Genotype	1984/85					1985/86		
	Jubeiha		Ramtha	Maru		Jubeiha		Ramtha
	D_1	D_2	D_1	D_1	D_2	D_1	D_2	D_1
UJL 405	4.4	4.3	5.2	4.2	4.3	5.0	4.4	5.1
UJL 289	4.5	4.0	5.1	3.4	3.8	4.8	4.5	5.5
76 TA 66088	2.8	2.5	3.8	3.2	2.9	3.3	3.4	3.9
ILL 4401	3.8	3.4	3.5	3.1	2.9	3.6	3.5	4.2
UJL 176	4.1	3.4	5.1	3.9	3.8	4.7	3.9	4.8
UJL 510	5.1	5.3	7.1	6.0	4.2	6.4	6.3	7.4
ILL 4400	5.1	6.0	6.9	6.5	4.1	6.6	5.4	6.7
78 S-26013	3.3	3.6	3.8	3.0	2.8	3.3	3.4	4.2
Precoz	4.1	4.3	5.6	4.5	4.1	4.8	4.4	4.4
Winter lik-51	3.7	4.0	3.6	3.4	3.1	3.9	3.3	4.1

LIST OF ABBREVIATIONS

Word or Sentence	Abbreviation
And others	et al.
Atmosphere	atm.
Centimeter	cm
Coefficient of Determination	r^2
Degrees of Freedom	D.F.
Gram(s)	g
Hectare	ha
Kilogram(s)	kg
Meter	m
Milligram	mg
Millimeter	mm
Percent	%