

RESULTS AND DISCUSSIONS

PART - I

4.1. Effect of Soil Moisture Stress on Bulb Production

4. RESULTS & DISCUSSIONS

4.1.1. ONION GROWTH:

The simplest definition, commonly used by botanists for growth is an increase in cellular mass (size, dry weight) although there are some instances which are considered as growth without any accompanied increase in weight (germination of seeds). Increase in size and weight is only one feature of growth.

4.1.1.1 Plant Height:

Plant height at successive stages of onion growth under different levels of soil moisture through the period of study is presented in Table (3) and illustrated in Figure (2). Onion height, either leaf blade, leaf base or sum of them increased by advancing age. Soil moisture stress, in general had a highly significant effect on the height of onion. This trend was found to be obvious in both seasons (82 & 83) and at the three stages. Increasing water deficit up to 80% depletion did result in a highly significant decrease in onion height either leaf blades or leaf base. This means that irrigating onion plant at 80% depletion in available water significantly retarded onion growth thereby decreased its length. Such trend can be explained on the basis of the effect of water deficit on the growth of plants.

Water stress has a direct effect on cell turgor through two important phenomena; stomatal closure & cell enlargement. Complete or almost complete closure of stomata can therefore markedly reduce both

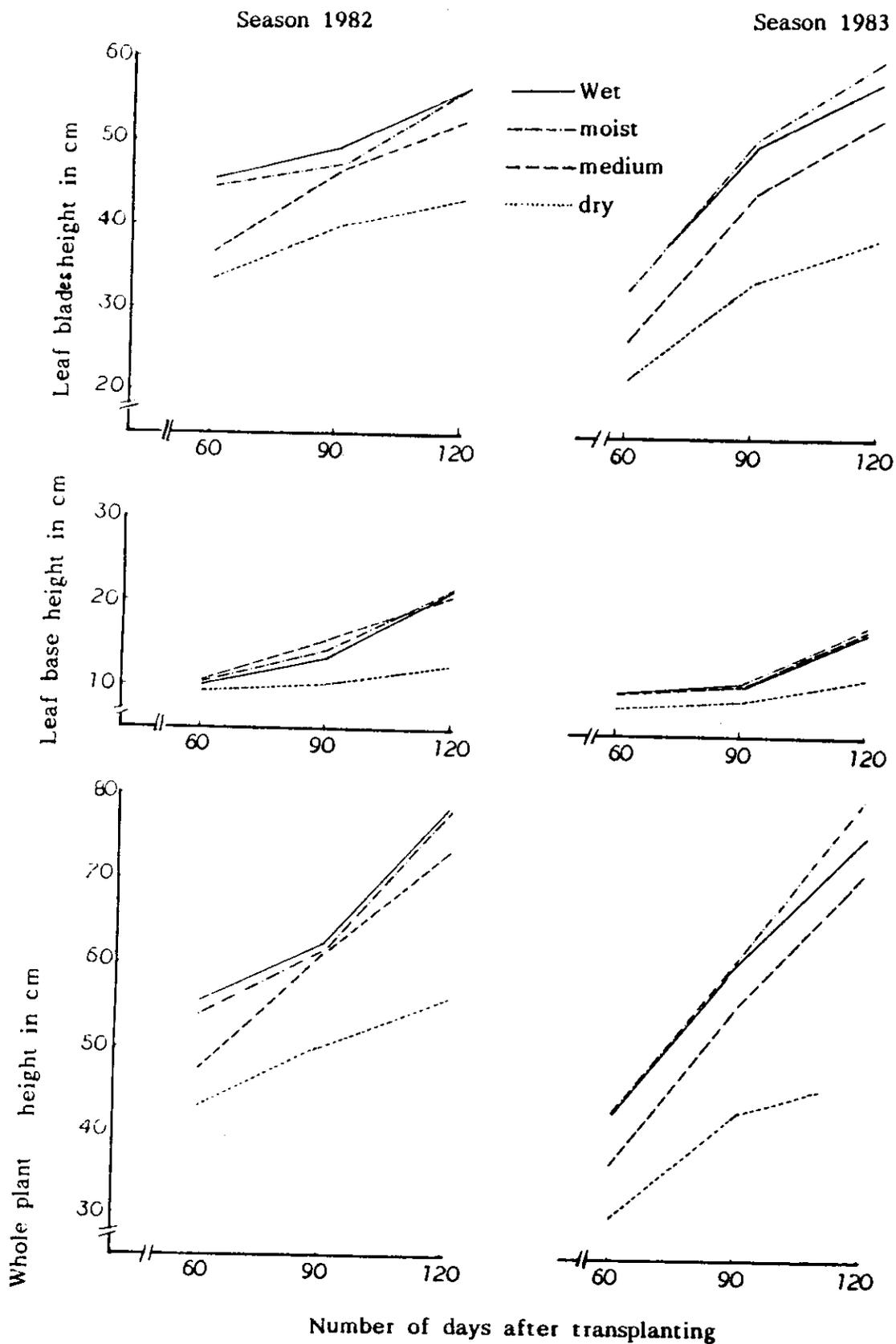


Fig.(2): EFFECT OF WATER DEFICIT ON THE HEIGHT OF DIFFERENT ONION PLANT PARTS AT SUCCESSIVE PERIODS OF GROWTH IN CM (Seasons 1981/82 and 1982/83).

processes and so ultimately reduces growth. Many of the detrimental effects of water deficits at moderate stress levels, can be attributed to stomatal closure since the energy balance of the leaf is also affected out leaf temperature may rise to damaging. In this respect, Kramer (1977) mentioned that maximum level of turgor is essential for cell enlargement.

4.1.1.2. Number of Leaves

Leaf number at the three successive stages of onion growth under different levels of soil moisture is presented in Table (4). In general, the time trend of leaf number shows an increase up to a maximum till 120 days after transplanting. It seems that the plant in early stages uses most of its gain in dry weight in producing new leaves preparing itself for the big rise in dry weight associated with bulb formation.

Soil moisture stress had no effect upon number of leaves/plant at the three sampling dates and the values were found to be insignificant. This pattern was confirmed in the second season. (Table 4). It can be concluded that water deficit might have no promoting effect on number of leaves/plant. These results are in line with those reported by Basilious (1975).

Table (4): EFFECT OF WATER DEFICITS ON NUMBER OF LEAVES/PLANT, NECK DIAMETER, BULB DIAMETER, BULB DIAMETER AND BULBING RATIO OF ONION DURING ITS GROWTH CYCLE (Seasons1981/82 & 1982/83).

Plant age	60 days				90 days				120 days			
	Number of leaves	Neck diameter cm	Bulb diameter cm	Bulbing Ratio	Number of leaves	Neck diameter cm	Bulb diameter cm	Bulbing Ratio	Number of leaves	Neck diameter cm	Bulb diameter cm	Bulbing Ratio
	Season (1981/82)											
Wet (A)	4.7	0.89	1.08	1.23	5.33	1.26	2.13	1.69	6.53	1.65	3.94	2.39
Moist (B)	5.2	0.78	1.04	1.33	5.70	1.26	1.98	1.56	6.66	1.70	3.69	2.17
Medium (C)	5.6	0.79	1.20	1.52	5.83	1.06	2.36	2.21	6.83	1.41	3.58	2.54
Dry (D)	5.2	0.65	1.07	1.65	5.28	1.03	2.02	1.95	6.46	1.30	3.03	2.33
Sig. level	N.S	**	N.S	N.S	N.S	**	N.S	N.S	N.S	**	*	N.S
L.S.D. at 0.05		0.11				0.12				0.15		0.45
	Season (1982/83)											
Wet (A)	5.30	0.71	0.89	1.268	6.3	1.06	1.37	1.29	7.10	1.34	4.00	2.98
Moist (B)	5.60	0.69	0.97	1.405	6.66	0.85	1.23	1.44	6.90	1.30	3.27	2.52
Medium (C)	5.73	0.65	0.94	1.441	5.99	0.73	1.39	1.90	6.66	1.23	4.20	3.41
Dry (D)	5.8	0.52	0.80	1.550	6.86	0.69	1.29	1.87	6.33	0.84	2.62	2.94
Sig. level	N.S	**	N.S	N.S	N.S	**	N.S	N.S	N.S	**	*	N.S
L.S.D. at 0.05		0.05				0.13				0.17		0.74

4.1.1.3. Neck Diameter:

The differences in neck diameter in relation to water deficits at different developmental stages are brought out in Table (4). Data clearly show that neck diameter increased with advancing age. This increase seems to be mainly due to the increasing number and or increasing thickness of leaf stretch produced at different stages. Such trend may indicate that the neck diameter increased progressively with time.

Regarding the effect of soil moisture stress on neck diameter, results obtained from the two seasons revealed that increasing water deficits did result in a significant decrease in neck diameter at all stages. This trend means that neck diameter is favoured by wet condition rather than dry levels. The highest values were obtained from wet treatment (irrigated after the depletion of 20%) and the lowest one was gained from the dry level (irrigated after 80% depletion in available water). However, the values from the moist or medium irrigation levels fall in between without any significant differences between them in the most of the figures.

It can be mentioned that severe moisture stress (80% depletion in available water) caused a highly significant decrease in neck diameter. In other words, the increase in neck diameter is favoured by wet conditions rather than dry ones.

4.1.1.4. Bulb Diameter

It is apparent from Table (4) that bulb diameter increased as the onion plant developed up to 120 days from transplanting. This trend can be ascribed to the higher number of swollen foliage leaf base, scales (bladeless leaves) as well as their increase in thickness by time. All of these accounted for greater values of bulb diameter observed at later stages of onion growth.

Concerning the effect of water deficit on bulb diameter data obtained in Table(4) revealed that water deficit had no effect on bulb diameter at 60 or 90 days from transplanting. In both stages the values between the four levels of irrigation were insignificant. This pattern may show that water deficit through these periods did not affect such character. At later stages, of development (120 days), soil moisture stress significantly decreased bulb diameter, in both seasons. It is worthy to mention that no significant differences were found between the wet, moist and medium soil moisture levels. However when water deficit increased more than 60% in available water (80% depletion) bulb diameter decreased significantly at later growth stages. A point being important to stress is that for maximum bulb diameter, medium level of irrigation is preferable.

4.1.1.5 Bulbing Ratio:

The relation between the greatest diameter near the base and

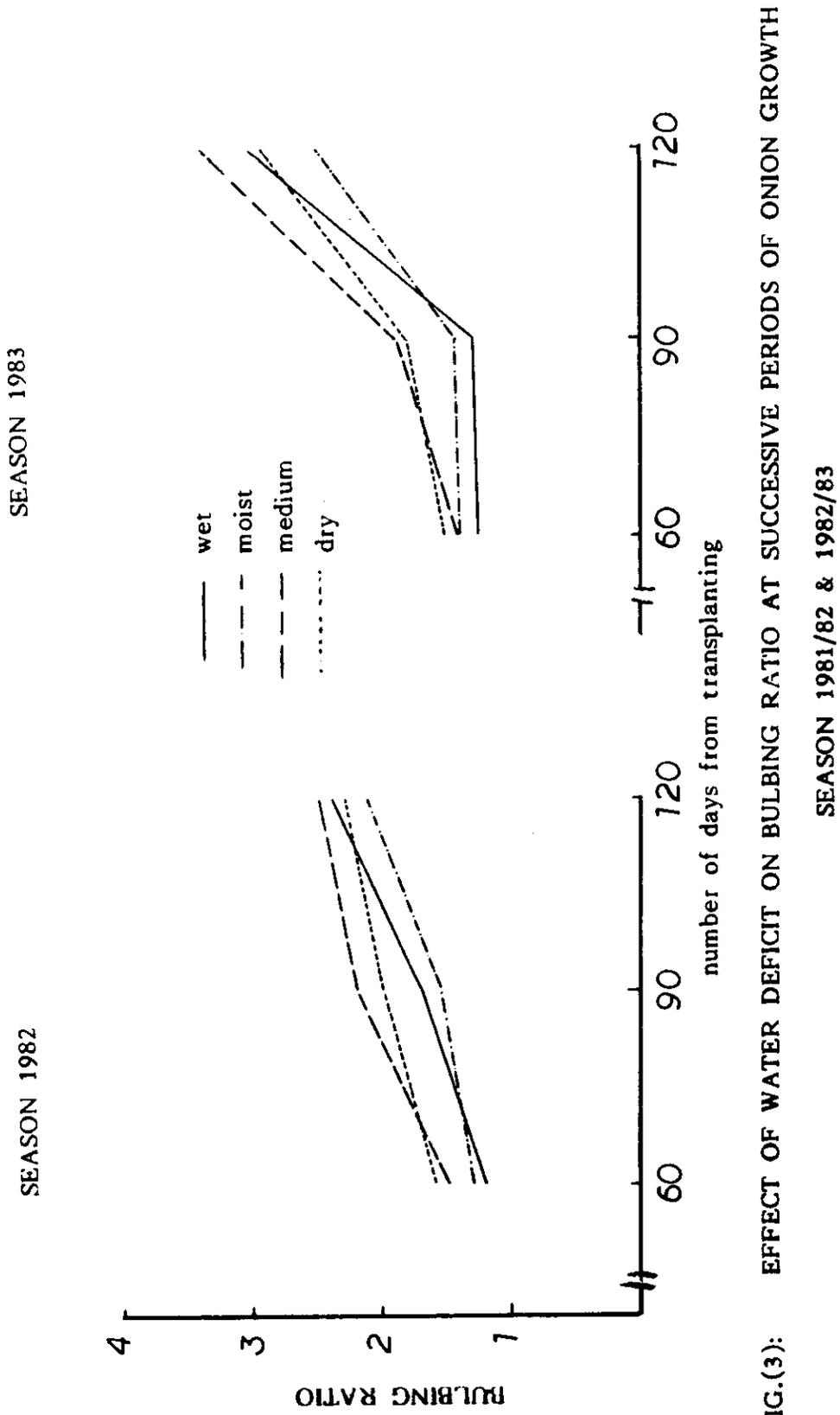


FIG.(3): EFFECT OF WATER DEFICIT ON BULBING RATIO AT SUCCESSIVE PERIODS OF ONION GROWTH

SEASON 1981/82 & 1982/83

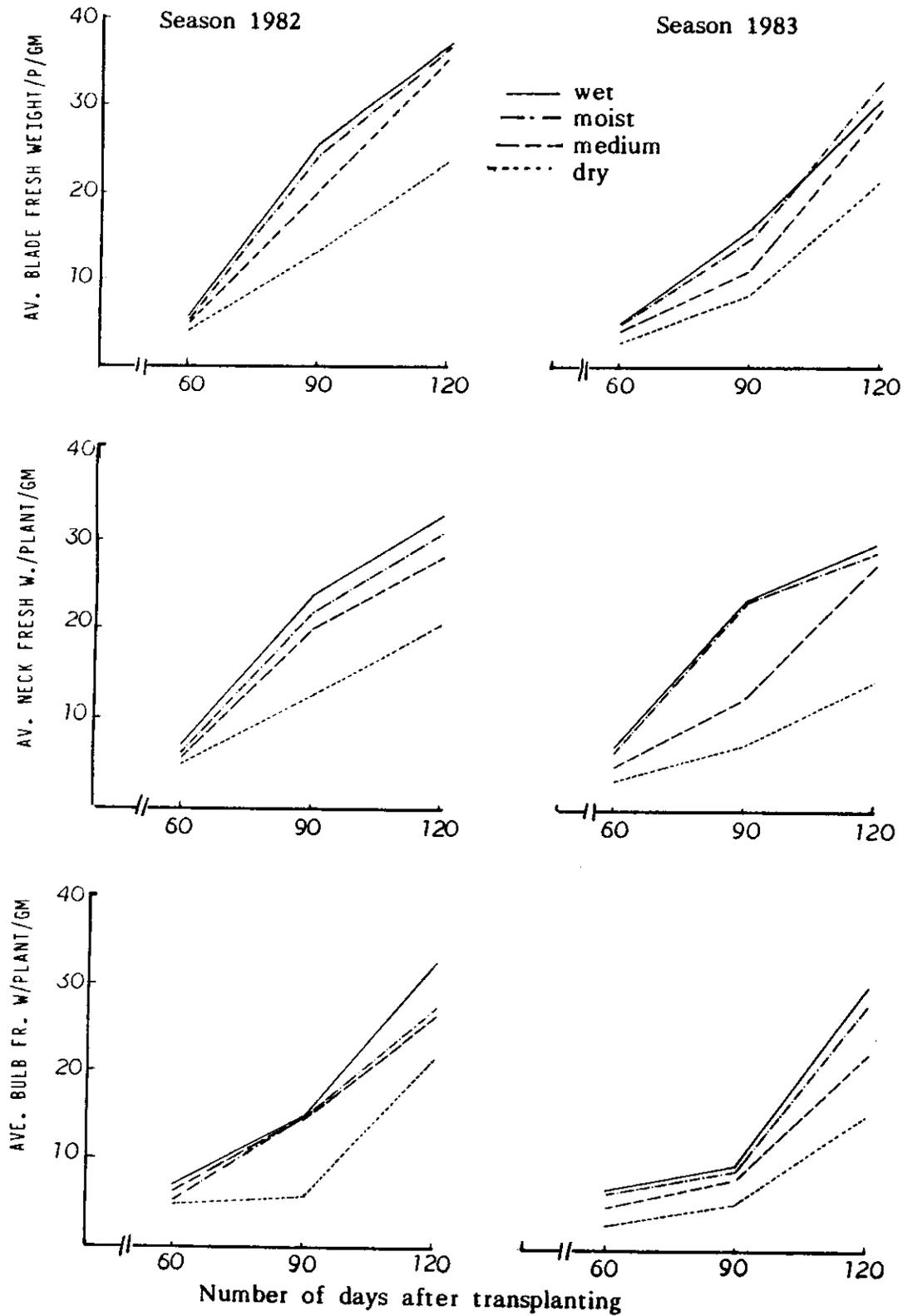
the minimum neck diameter (bulbing ratio) can be regarded as an assessment of bulb development. It has been reported by Mann (1952) with garlic that any ratio above 2 indicates definite bulb formation and ratios above 5 indicate maturing bulb. It can be seen from Table (4) and Figure (3) that bulbing ratio showed an increase in its value as the onion plant developed up to 120 days after transplanting. At this time the bulbing ratio seemed to be more than 2 which indicates their full formation at this age. With regard to the role of soil moisture stress on bulbing ratio, data recorded in Table (4) and illustrated in Figure (3), showed no significant response to water levels in both seasons of study and the values were about the same between the four water regimes. However, the medium soil moisture stress scored the maximum value of bulbing ratio in the three stages of onion growth. These findings were confirmed by Basilious (1975) who concluded that more frequent irrigations tended to delay bulbing.

4.1.1.6 Foliage Fresh Weight

Fresh weight of different onion plant parts i.e. blade, neck and bulb as well as the whole plant throughout its growth cycle in both seasons (1982 and 1983) is presented in Table (5) and graphed in Figures(4 and 5).

Table (5): EFFECT OF WATER DEFICIT ON THE FRESH WEIGHT OF DIFFERENT ORGANS OF ONION PLANT (g/plant)
 AT SUCCESSIVE PERIODS OF GROWTH. (Season 1981/82 & 1982/83).

Plant age	60 days				90 days				120 Days			
	Leaf blade	leaf base	whole plant	leaf blade	leaf blade	Neck	Bulb	Whole plant	leaf blade	Neck	bulb	whole plant
	Season 1981/1982											
Wet (A)	5.61	7.37	12.98	25.55	23.94	10.69	60.19	36.90	32.88	32.96	102.74	
Moist (B)	6.22	5.39	11.61	24.21	22.05	10.56	56.83	36.27	30.92	27.60	94.70	
Medium (C)	5.04	6.37	11.41	20.19	20.04	10.39	50.62	35.69	28.35	26.84	90.88	
Dry (D)	4.26	4.92	9.18	13.83	12.44	6.08	32.35	23.78	20.96	22.05	66.79	
Sig: Level	*	**	**	**	**	**	**	**	**	**	**	
L.S.D. at 0.05	1.49	1.09	1.71	3.93	5.24	2.78	8.77	4.59	6.91	2.75	10.21	
	Season 1982/83											
Wet (A)	5.51	7.15	12.66	16.14	23.83	9.88	49.85	30.73	30.02	30.90	91.66	
Moist (B)	5.40	6.56	11.96	15.86	23.66	9.55	49.08	33.02	29.04	28.28	90.34	
Medium (C)	4.08	5.07	9.14	11.74	12.74	8.12	32.60	29.89	27.36	22.40	79.65	
Dry (D)	2.73	3.60	6.33	8.88	7.46	6.41	22.75	21.34	14.58	15.12	51.03	
Sig. level	**	*	**	**	**	**	**	**	**	**	**	
L.S.D. at 0.05	0.59	1.42	0.88	5.51	4.51	2.53	11.17	6.87	8.65	5.27	15.26	



Fig(4) EFFECT OF WATER DEFICIT ON THE FRESH WEIGHT OF DIFFERENT ORGANS OF ONION PLANT (gm/plant) AT SUCCESSIVE PERIODS OF GROWTH. SEASON (1981/82 & 1982/83).

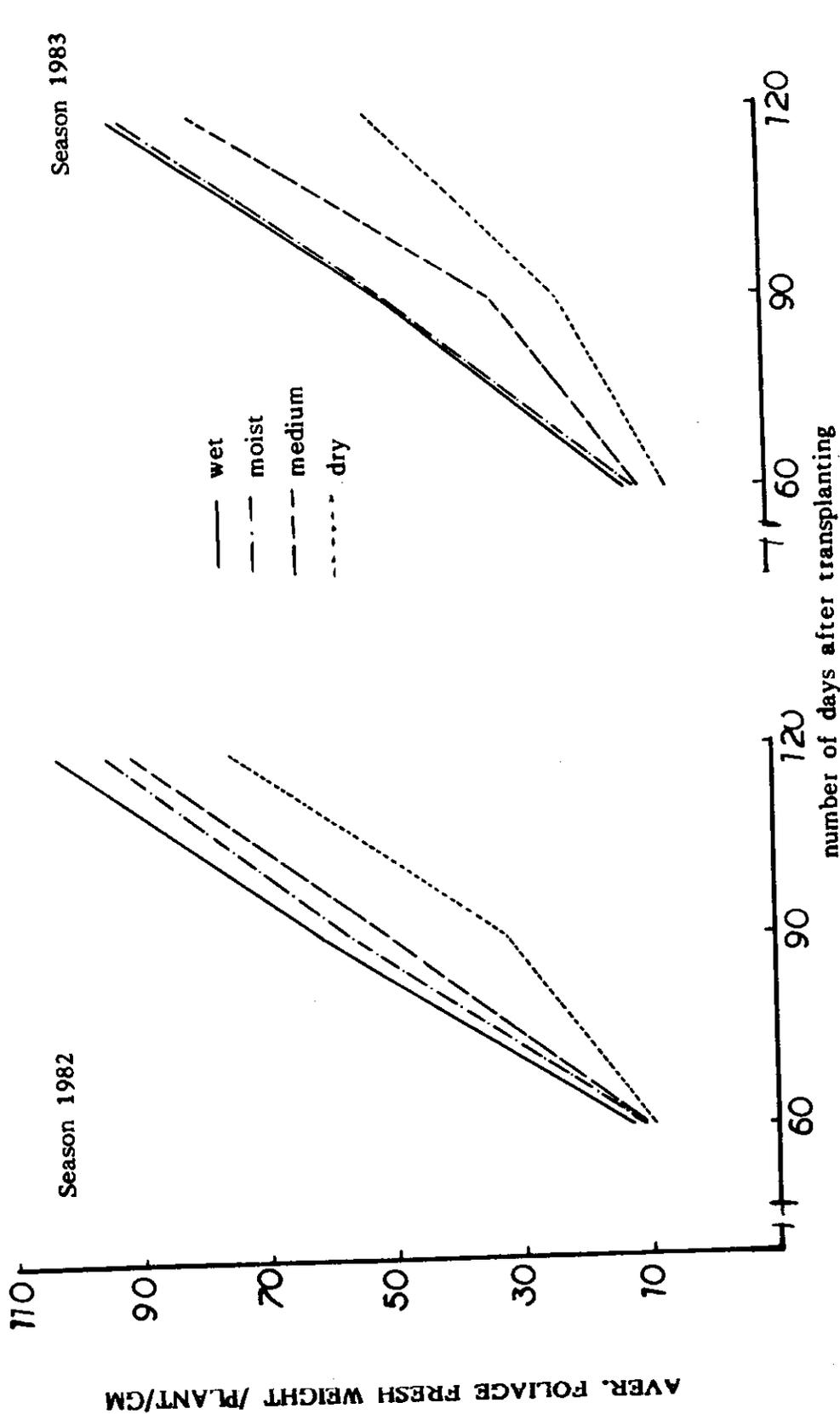


Fig.(5): EFFECT OF WATER DEFICIT ON FRESH WEIGHT OF WHOLE PLANT AT SUCCESSIVE PERIODS OF GROWTH SEASON 1981/82 & 1982/83

Under the conditions of the experiments fresh weight of different onion plant parts and the entire plant, increased progressively from transplanting till 120 days. This trend seemed to be true either in all treatments or in both seasons. Irrespective to irrigation treatments applied, plants increased slowly in weight between transplanting and 60 days after which a marked increase was observed till 120 days old. At this age, the fresh weight increased sharply. This big rise in fresh weight is connected with rapid bulb bulking which serves as an intense sink for photosynthates accumulation .

Concerning the influence of water deficit on the fresh weight of onion plant, results gained from the two seasons revealed that soil moisture stress has a highly significant effect on the fresh weight of onion plant. This is true at the three sampling dates either in different onion plant parts or for the entire plant. Such trend may indicate the importance of soil water for the growth of onion. Maximum value of fresh weight was obtained from wet treatment followed by moist and medium soil moisture levels without any significant differences between them. The least values were scored from the dry soil moisture treatment (80% depletion of available water). The reduction in fresh weight obtained from the dry treatment was highly significant over the three other water regimes. This trend was found to be true in the different onion plant parts as well as the whole plant. These results could be attributed to the stimulative effect of wet conditions

on the growth of onion. Under stress conditions, photosynthesis is reduced by closure of stomata thereby decreases the entry of CO_2 as well as reduces the capacity of protoplasm to carry on photosynthesis. All of these did result in reducing accumulation of net product thereby plant growth. In this connection, Kramer (1969) pointed out that water stress affects nearly every process in a plant and other factors in addition to turgor. Turgor pressure is low in enlarging cells, but some minimum level of turgor is necessary for cell expansion.

4.1.1.7 Dry matter Production:

Dry matter content of plant organs during its growth cycle may be considered as an indirect estimation of the level of physiological activities in the various tested plant parts. It is one of the most excellent expressions of plant growth behaviour.

Dry matter of different onion plant parts at various stages of its growth as affected by water deficit is given in Table (6) and illustrated in Figure (6).

Dry matter accumulation in the various onion plant parts starts with low amounts early in the season, then increased gradually with advancing age. The trend was found to be true in the different onion parts i.e. leaf blade, neck and bulb as well as the whole plant in the two seasons.

Table (6): EFFECT OF WATER DEFICIT ON DRY MATTER ACCUMULATION IN DIFFERENT ORGANS OF ONION PLANT (g/plant) AT SUCCESSIVE PERIODS OF GROWTH (Season 1981/82 & 1982/83).

Plant age	60 days					90 days					120 days				
	Leaf blade	leaf base	whole plant	leaf blade	Neck	Bulb	Whole plant	leaf blade	Neck	Bulb	whole plant	leaf blade	Neck	Bulb	whole plant
Season 1981/82															
Wet (A)	2.64	1.38	4.02	3.35	3.23	2.02	8.60	5.91	5.33	5.31	16.55	5.91	5.33	5.31	16.55
Moist (B)	2.30	1.61	3.91	3.21	2.86	1.84	7.91	5.70	5.14	5.18	16.07	5.70	5.14	5.18	16.07
Medium (C)	1.91	1.81	3.72	3.13	2.86	1.70	7.69	5.64	4.73	5.11	15.48	5.64	4.73	5.11	15.48
Dry (D)	1.82	1.42	3.24	2.67	2.38	1.18	6.23	4.54	3.60	4.15	12.29	4.54	3.60	4.15	12.29
Sig. level	**	N.S	*	*	*	*	**	**	**	**	**	**	**	**	**
L.S.D. at 0.05	0.32		0.34	0.43	0.42	0.47	1.04	0.70	0.98	0.68	2.01	0.70	0.98	0.68	2.01
Season 1982/83															
Wet (A)	1.47	1.80	3.27	2.52	3.55	2.40	8.47	5.52	5.52	5.23	16.27	5.52	5.52	5.23	16.27
Moist (B)	1.38	1.42	2.80	2.34	2.90	1.92	7.16	5.82	5.76	5.30	16.88	5.82	5.76	5.30	16.88
Medium (C)	1.22	1.53	2.75	2.16	2.52	2.16	6.84	5.19	5.16	4.80	15.16	5.19	5.16	4.80	15.16
Dry (D)	0.90	1.31	2.21	1.44	1.56	1.92	4.92	3.64	3.12	3.34	10.09	3.64	3.12	3.34	10.09
Sig. level	**	N.S.	*	*	**	N.S	*	**	**	**	**	**	**	**	**
L.S.D at 0.05	0.26		0.51	0.32	0.47	1.99	1.04	1.04	0.73	1.12	3.85	1.04	0.73	1.12	3.85

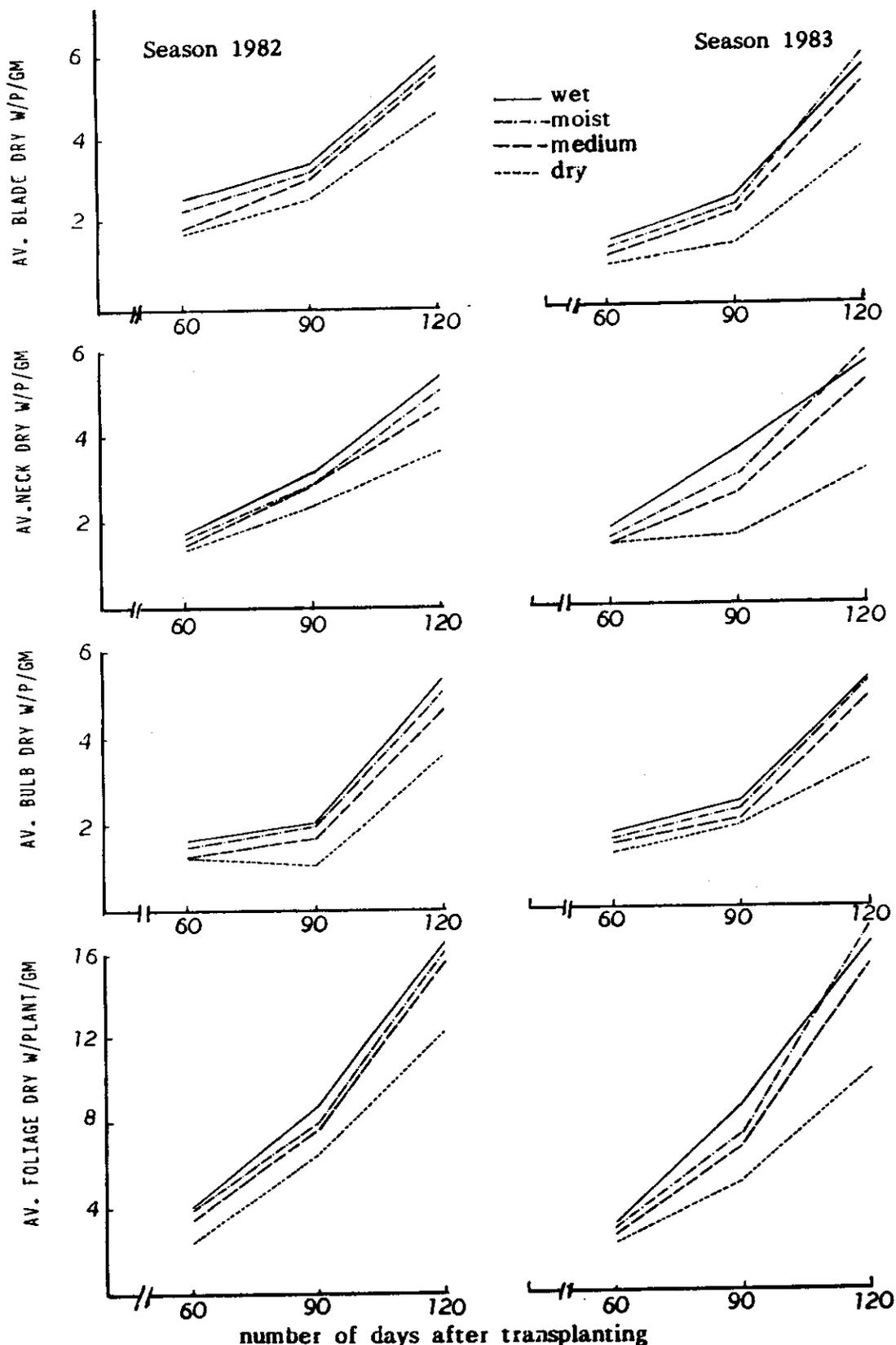


Fig.(6) EFFECT OF FWATER DEFICIT ON DRY MATTER ACCUMULATION IN DIFFERENT ORGANS OF ONION PLANT (gm/plant) AT SUCCESSIVE PERIODS OF GROWTH SEASON (1981/82 & 1982/83)

With regard to the effect of water deficit on dry matter accumulation by onion plant, the dry matter followed more or less the same trend as fresh weight. In other words, dry matter increased as soil moisture stress decreased and the reverse was found to be true. Statistical analysis had shown that the effect of water deficit on the dry matter either of various parts or the whole onion plant

was highly significant. A point of interest is that no significant differences were observed between wet, moist and medium soil moisture levels. However, the dry treatment significantly produced the least value of dry matter compared with the three other moisture levels. This trend may show that dry matter accumulation is favoured by high soil moisture contents and decreased by increasing soil moisture stress and ceased when soil water falls from field capacity to wilting. In this respect, De Lis et al (1967) concluded that onion is differentially sensitive to drought at each stage of its growth cycle. When drought occurred at the beginning of bulb formation, bulb weight was decreased.

4.1.1.8. Dry Matter Distribution:

The effect of water deficit on the growth of different plant organs expressed as absolute weight has been discussed previously. Of further interest is the question in how far the growth of each of plant organs, expressed as a percentage of the entire plant weight, is affected by water deficit. Not only is this expression of theoretical

Table (7): EFFECT OF WATER DEFICITS ON PERCENTAGE DISTRIBUTION OF DIFFERENT PLANT ORGANS AT VARIOUS PERIODS OF GROWTH AS RELATED TO THE WHOLE ONION PLANT (Season 1981/82 & 1982/83).

Plant age	60 days			90 days			120 days		
	Blade	leaf base	Bulb	Blade	Neck	Bulb	Blade	Neck	Bulb
	Season 1981/1982								
Wet (A)	65.67	33.33	38.95	37.56	23.49	35.71	32.21	32.08	
Moist (B)	58.82	41.17	40.58	36.16	23.26	35.47	32.30	32.23	
Medium (C)	51.34	48.66	40.70	37.19	22.11	36.43	30.56	33.01	
Dry (D)	56.17	43.82	42.86	38.20	18.94	36.94	29.29	33.77	
	Season 1982/83								
Wet (A)	44.95	55.04	29.75	41.91	28.33	33.92	33.92	32.15	
Moist (B)	49.28	50.71	32.68	40.50	26.81	34.47	34.12	31.40	
Medium (C)	44.36	55.63	31.58	36.84	31.58	34.26	34.06	31.67	
Dry (D)	40.72	59.28	29.27	31.71	39.02	36.04	30.89	33.07	

interest, but may also be of considerable practical importance.

Table (7) represents water deficit effects on growth of leaf blades, neck and swollen neck base (bulb) expressed as percentage of the total dry weight of the plant during seasons 81/82 and 82/83. As a general, leaf blades comprised the main plant dry matter component during the first period of onion growth (60 days after transplanting). At this period, leaf blades comprised more than 60% of total dry matter of onion plant. As the onion plant developed, dry matter of leaf blades decreased gradually to reach a minimum at 120 days. Such decrease in leaves dry matter is associated with an increase in the dry matter of both neck and bulb. This trend is mostly connected with the accumulation of dry matter in leaf base or bulb. However, at later stage of onion growth, the distribution of dry matter in the three organs i.e. leaf blades, neck and bulb are equal and approximately about 33% of the total dry matter produced by the plant.

The previous results may be interpreted on the assumption that onion plant directed its effort to stimulate higher proportion of the accumulated dry matter to the developing leaf blades early in the season(60 days). Later on, onion plant directed its effort for building up the bulb. In other words, dry matter is redistributed from leaf blades to the swollen neck base (bulb). These results can be explained on the basis of that there is a regulating mechanism that redistributes

dry matter within the plant parts and that depends on the growth period.

With regard to the effect of soil moisture stress on the distribution of dry matter within the different plant parts of onion, the results gained from Table (7) revealed that water deficit did result in lowering the proportion of dry matter of leaves at early stage (60 days) compared with those grown under wet conditions. This trend may prove the importance of soil water for the growth of onion leaf blades. In other words, soil moisture is very important for the growth of onion leaves early in the season. However, at later stages or as the onion plants developed the proportion of dry matter of leaf blades increased by water deficit on the account of the decrease in dry matter of both neck and bulb. This pattern may show to what extent the dry matter accumulation in neck and bulb was affected by the level of soil moisture. Dry matter of neck and swollen base (bulb) is favoured by wet condition at later stages (90 and 120 days after transplanting). In both stages, the opposite trend was found to be true with respect to the growth of blades.

In the light of the previous results, it can be concluded that the availability of water proves to be one of the chief constraints on dry matter productivity thereby, its distribution in the different onion plant parts. Total net photosynthesis is determined by the :

- a) Availability of light, CO₂ water and nutrients
- b) The growth pattern of the plant that determines both photosynthesis rate,
- c) The reinvestment rate and
- d) The response of plant to stress.

In this respect, Hagan et al (1957) found that total green weight production was reduced significantly with decreasing soil moisture. Also, Parker (1968) pointed out that leaves are often the most sensitive part of the plant to drought and at the same time they are essential for the process of food manufacture.

4.1.2 BULB YIELD

4.1.2.1. Total Yield:

Total bulb yield of onion expressed in Tons/feddan as influenced by different levels of soil moisture stress during the period of study is shown in Table (8). Statistical analysis of the variance showed that soil moisture levels had a highly significant effect upon the production of bulbs by onion crop. This trend was found to be the same in the three seasons.

Results obtained showed that maximum bulb yields were produced from the three irrigation treatments, i.e. wet, moist and medium levels.

It is worthy to mention that the differences between the three water regims were found to be statistically insignificant. In other words, the bulb yield produced from those irrigation levels were about the same. However, increasing soil moisture stress more than 60% in available water i.e. irrigating onion at 80% depletion did result in a highly significant decrease in bulb yield.

The previous results may indicate that maintaining soil moisture at low or moderate levels produced the highest yield of bulb. On the contrary, subjecting onion plant to severe moisture stress (80% depletion in available water) caused a sharp decrease in the total bulb yield of onion. These results may prove the importance of soil water for increasing the productivity of onion. These findings are in full agreement with those reported by Waly (1973), and Basilious (1975) who pointed out that bulb crop irrigated at 50% depletion in available water outyielded those irrigated after 75 or 100% depletion in available water.

In this connection, Kramer (1977) concluded that reduced cell turgor is the most important reason for reduced plant size. Plant turgidity is important in relation to the opening and closing of stomata, expansion of leaves and movement of water and nutrients to various parts of the plants. Doorenbos et al (1979) pointed out that onion is sensitive to water deficit, for high yield soil water depletion should

not exceed 25% of available soil water. When the soil is kept relatively wet, root growth is reduced and this favours bulb enlargement.

4.1.2.2. Exportable Yield:

Exportable bulb yield of onion is that yield after excluding doubles, bolters and pickles. Yield data of exportable onion under the various levels of soil water through the period of study is presented in Table (8). Results clearly show that water deficit has a highly significant response on the exportable bulb yield of onion in the three seasons. The maximum exportable bulb yield was scored from the medium level of soil water which was irrigated after the depletion of 60% of the available soil moisture. The lowest value of exportable bulbs was gained from the dry treatment (80% depletion in available water). However, wet and moist water produced intermediate values. This trend of findings is true for the three seasons of study.

It is worthy to mention that the increase in bulb yield gained from medium soil moisture stress was found to be significant over both wet and moist water regimes and highly significant over that produced from the dry one. In other words, imposing onion plants to severe water deficit did result in a sharp reduction in bulb yield. Such reduction was found to be highly significant over the other three levels of water deficit. This trend may show that onion crop is

most sensitive to severe moisture stress, and adequate water supply is very important for bulb formation. In this respect Doorenbos et al (1979) concluded that to achieve large bulb size and high bulb weight, water deficit, especially during the yield formation period should be avoided.

In the light of the previous results, it can be mentioned that higher bulb yield of onion expressed as exportable yield is probably attained by irrigating onion plant when not more than 60% available water is depleted from soil profile. Soil moisture depletion beyond that level sharply decreased bulb yield. However, high moisture level or over that depletion (20 and 40% depletion) caused an increase in non-exportable product i.e. doubles and bolters which did result in reducing the exportable yield. These results may show that plant water deficits affect every aspect of plant growth by modifying the morphology and physiology of plants.

4.1.2.3. Non Exportable Bulbs:

Non exportable products are those maleformed bulbs which are not accepted by international market but may be used for local consumption. These bulbs include the doubles, bolters and pickles. Table (8) represents the effect of water deficit on the amount of non exportable bulbs (double, bolter, pickles and nonformed bulbs) as well as percentage of the total yield

Results clearly show that double bulbs weight decreased as soil moisture stress increased in the 3 seasons. Taking into account the doubles as a percentage from total production, the values in Table (8) showed a similar trend to that observed in their weight. In other words, frequent irrigation enhanced the formation of double bulbs. These results are in full agreement with those reported by Basillious (1975) who concluded that there was a tendency towards a decline in number of doubles with less frequent irrigations.

With regard to the effect of water regime on weight of bolters or their percentage of total yield, results illustrated in Table (8) showed no clear trend concerning such character. However, there is a tendency towards a decline in bolter weight by the increase in soil moisture stress up to 60% depletion in available water. Increasing water deficit more than 60% depletion did result in increasing bolter weight/feddan. In other words, the emergence of bolter from onion doubles may be enhanced either by wet condition or severe moisture stress. In this respect, Waly (1973) found no relevance between water regime and the percentage of early flowering plants (bolters).

Concerning the influence of water deficits on the weight of pickles, data presented in Table (8) indicate that pickles production seemed to be increased progressively as soil moisture stress increased. The reverse was found to be true in the three seasons of study.

These findings can be ascribed to the effect of water deficit on the accumulation of dry matter in bulbs. Previously it has been shown that dry matter accumulation in bulbs increased under wet conditions and decreased by water deficit. These results may explain the increase in weight of pickles/feddan by prolonged irrigation intervals.

4.1.2.4. Average Bulb Weight:

Results concerning average bulb weight as influenced by water regime is presented in Table (9). Statistical analysis showed that water deficit has a highly significant effect upon the average onion bulb weight. Such results was found to be similar in the three season.

The wet treatment has the maximum value of bulb weight followed by moist and medium soil moisture levels without any significant differences between them. However, the dry regime produced the lowest value of bulb weight. These results may show that prolonged irrigation intervals i.e. irrigating onion after the depletion of 80% in available water did result in smaller bulbs or a less bulb weight. The previous results can be ascribed to the effect of soil moisture stress on the growth of onion plant thereby on the weight of bulb.

4.1.2.5. Bulb Diameter:

This character was greatly affected by irrigation regime

Table (9): EFFECT OF WATER DEFICIT ON WEIGHT AND DIAMETER OF BULB, DRY MATTER% AND TOTAL LOSS% AFTER 4 MONTHS STORAGE.

Treatment	Bulb weight gm	Bulb diameter cm	Dry matter percentage	Total loss% after 4 months storage
<u>Season 1981/82</u>				
Wet (A)	81.3	6.81	15.15	27.86
Moist (B)	77.59	6.03	15.60	27.80
Medium (C)	73.63	5.36	16.14	22.63
Dry (D)	61.41	4.24	16.59	16.95
Sig. level	**	**	*	**
L.S.D. at 0.05	9.74	0.41	0.24	2.80
<u>Season 1982/83</u>				
Wet (A)	61.90	6.65	15.44	26.34
Moist (B)	59.63	4.26	16.65	27.10
Medium (C)	56.52	4.31	16.22	21.95
Dry (D)	46.06	3.06	18.71	17.49
Sig. Level	**	**	**	**
L.S.D. at 0.05	5.32	0.39	0.52	2.37
<u>Season 1984/85</u>				
Wet (A)	82.33	6.61	14.43	29.15
Moist (B)	69.39	5.93	15.60	26.97
Medium (C)	56.8	5.70	16.79	22.42
Dry (D)	47.11	4.55	17.11	17.57
Sig. level	**	**	**	**
L.S.D. at 0.05	9.40	0.28	0.26	3.17

(Table: 9). Bulb diameter was increased significantly by decreasing soil moisture stress and the reverse was found to be true. In other words, frequent irrigation produced larger bulb, while prolonged irrigation intervals decreased bulb diameter significantly. This trend can be attributed to the accumulation of dry matter in onion bulbs which was favoured by wet conditions rather than the dry soil moisture levels.

4.1.2.6. Percentage of Dry Matter in Bulbs

Table (9) represented the effect of soil moisture stress on the percentage of dry matter in onion bulb at harvest time. Results clearly show that dry matter percentage was significantly affected by the level of soil moisture. Lower dry matter percentage was produced under wet condition and tended to increase by increasing soil moisture stress. The maximum value of dry matter percentage was scored from the dry soil moisture level which was irrigated after the depletion of 80% in available water. These findings indicated that the moisture content in the bulbs at harvest time was higher under wet conditions and tended to decrease significantly by increasing soil moisture stress. These results are in full agreement with those reported by Basilious (1975) who pointed out that dry matter in bulbs tended to be greater with decreasing irrigation level.

4.1.2. 7. Total Loss in Bulb Weight After Storage:

Results of total loss in bulb weight after 4 months of storage under different irrigation levels were given in Table (9). Statistical analysis of the variance showed a highly significant effect of water deficit on the loss of bulb weight after storage during the period of study. It was found that decreasing soil moisture stress prior irrigation did result in a highly significant increase in the total loss in bulb weight during storage. These results showed that the moisture in bulbs was higher with frequent irrigation and decreased by the elongation of irrigation intervals. Wet condition seemed to increase the amount of moisture in bulbs which may be less by storage. Those patterns may explain the higher percent of loss in bulb weight after storage from those treatment irrigated frequently or after the depletion of little amount of available water.

The previous results are in line with those reported by **Warid et al (1961) and Waly (1973)**. According to **Paterson and Faskett (1949)** the poor keeping quality of onions seemed to be associated with less dry matter content of bulb. On the contrary, storagability of onion was either improved or not influenced by the increase in soil moisture level, [**Mac Gillivery (1950) Drink water and Janes (1955), Thomase (1968) and Vaseckij (1971).**]

4.1.3. Evapotranspiration (ET):

Evapotranspiration or water consumptive use is defined as the combined process by which water is transferred from the earth's surface to the atmosphere. It includes evaporation of water from the soil and plant plus transpiration of liquid water through plant tissues expressed as the latent heat transfer per unit area or its equivalent depth of water per unit area (Burman et al, 1980). Evapotranspiration from a plant - soil surface is proportional to the vapour pressure gradient between the surface and the free air above the surface and inversely proportional to the resistance of the diffusion pathway. The vapour pressure at the plant or soil surface depends on the net radiation at the surface which in turn is a function of surface energy budget. Plant factors undoubtedly influence evapotranspiration from a crop. The greatest difference among crops occur during the growth period when the crop cover is less than 80%. (Gates & Hanks 1967).

4.1.3.1. Actual Evapotranspiration

4.1.3.1.1. Seasonal Rates:

Seasonal values of evapotranspiration by onion (bulb crop) as a function of water deficits during the three seasons of study are presented in Table (10). Water consumptive use rates ranged from

18.83 to 36.27 cm, 17.17 to 34.24 cm and 18.04 to 35.62 cm for the first, second and third seasons respectively.

The previous results clearly indicate that water consumption by onion was higher in the first season than either the second or the third seasons. This is mainly due to differences in climatic conditions. These findings are in line with those reported by Chang (1971) who concluded that the rate of evapotranspiration depends on the evaporative power of the air as determined by temperature, humidity and net radiation. Also, Jensen (1968) pointed out that crops such as small grains would not necessarily require the same amount of water when grown in different regions under widely different climatic conditions or when grown at different times during the year at a given location. Doorenbos et al (1979) concluded that for optimum yield, onion requires 350 to 550 mm water.

Table (10) represents the seasonal water consumptive use by onion under different soil moisture stress over the period of study. Also figure (7) represents the cumulative water consumptive use by onion mean of the seasons as a function of water regimes. Results indicate that water consumption was increased as soil moisture stress decreased. The highest evapotranspiration rate was brought about under wet condition (low soil moisture stress, 20% depletion in available water) whereas the lowest water use was attained under

TABLE (10): EFFECT OF WATER DEFICIT ON EVAPOTRANSPIRATION RATES OF ONION (Bulb crop)
IN mm FOR THE THREE SEASONS

EVAPOTRANSPIRATION RATES IN mm												
Months	Nov	Dec	Jan	Feb	Mar	April	Seasonal ET					
Treatments	15-30	1-15	16-31	1-15	16-31	1-15	16-30	mm				
	Season 1981/1982											
	20-30											
Wet (A)	16.17	20.85	22.27	26.08	28.17	34.15	48.44	65.34	63.84	37.43	362.7	
Moist (B)	16.17	20.85	18.65	24.65	27.72	29.89	42.45	58.41	52.24	32.56	323.6	
Medium (C)	16.17	18.96	16.63	20.52	25.12	37.18	44.11	40.09	30.90		275.6	
Dry (D)	16.17	17.30	12.96	12.15	12.96	21.37	25.95	27.09	25.62	16.80	188.34	
	Season 1982/1983											
	2-15											
Wet (A)	17.93	25.99	21.90	29.14	39.57	43.42	61.40	58.03	33.75	11.25	342.4	
Moist (B)	17.93	20.08	16.02	23.28	34.87	40.21	53.38	48.16	31.50	10.50	295.9	
Medium (C)	17.93	17.99	14.99	23.25	24.14	34.24	39.53	37.36	30.65	7.64	247.7	
Dry (D)	17.93	14.52	12.36	13.18	13.60	22.95	24.58	26.23	21.34	5.01	171.7	
	Season 1984/1985											
	29-30											
Wet (A)	2.93	21.97	20.06	24.27	25.86	35.95	46.58	64.42	62.17	35.51	16.57	356.3
Moist (B)	2.93	21.97	17.72	20.35	22.49	31.17	35.70	51.67	47.87	30.15	14.07	296.0
Medium (C)	2.93	21.97	17.27	18.75	20.00	27.88	29.12	36.20	36.20	30.15	13.93	254.4
Dry (D)	2.93	21.97	14.72	13.80	14.72	14.61	22.26	23.85	21.73	20.37	9.50	180.4

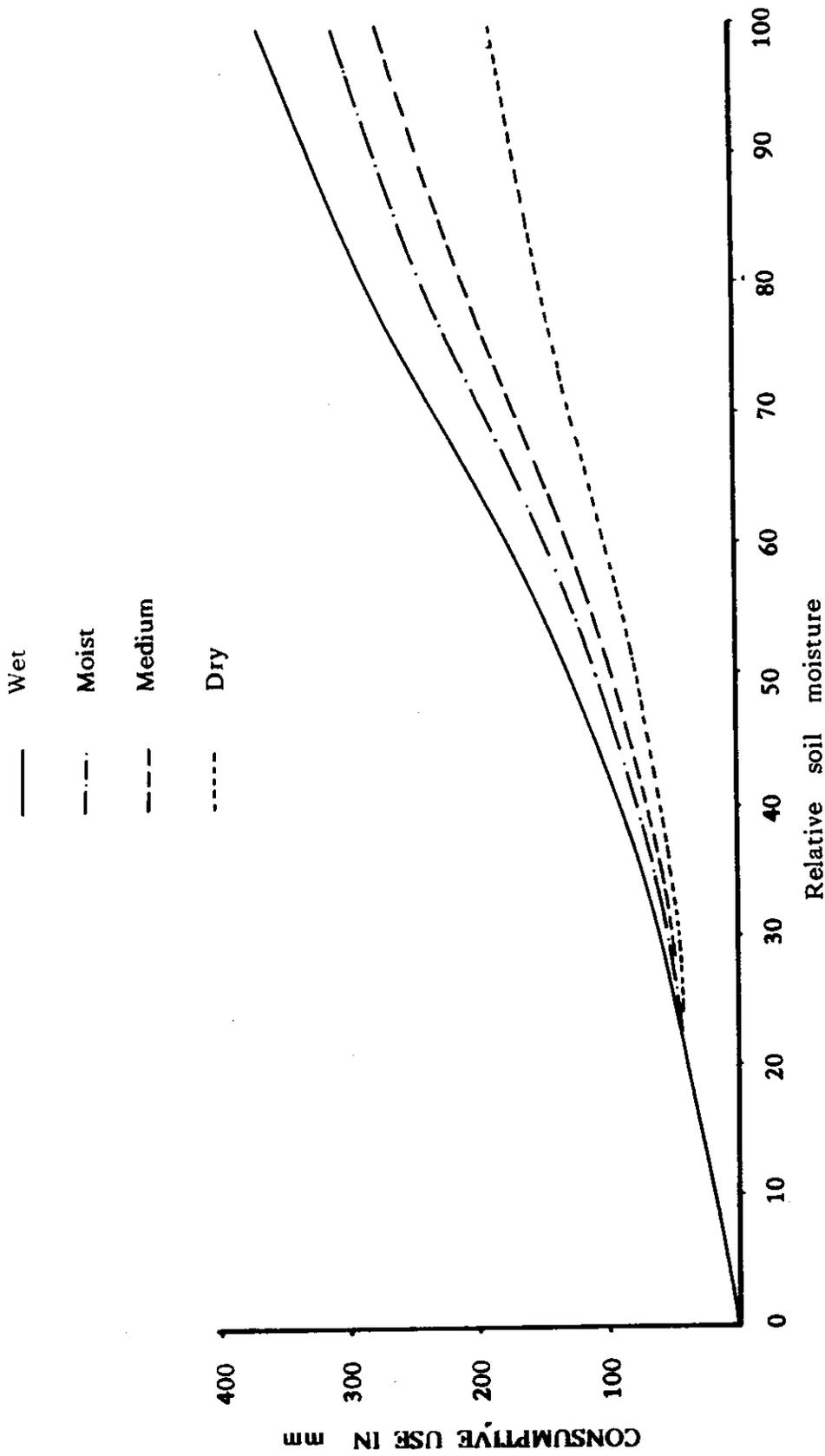


Fig.(7): CUMULATIVE WATER CONSUMPTIVE USE BY ONION (Bulb Crop) UNDER DIFFERENT SOIL MOISTURE STRESSES.

dry conditions (severe soil moisture stress, 80% depletion in available water). The values of moist or medium level of soil water (40 or 60% depletion) fall in between. In other words, the evapotranspiration rates increased in an ascending order dry < medium < moist < wet soil moisture levels. This phenomenon revealed that the increase in water consumption depends on the available soil moisture in the root zone. When soil was kept wet by frequent irrigation, maximum evapotranspiration was obtained. This trend is mainly due to the availability of soil water to the plants as well as at the soil surface

In this respect, Tanner et al (1960) stated that "on a given type of soil, the total evapotranspiration depends on the water available to the plants as well as that available at the soil surface and upon the total net radiation above plants and at the soil surface". Thorntwaite and Mather (1955) suggested a linear decline of evapotranspiration with increasing tension, based on the vapour pressure and temperature on soil. Wiegand (1962) pointed out that the drying rate of a bare soil is proportional to the water content and inversely proportional to time, and a drying front advances into the soil linearly with time. When the capacity of the soil to conduct water to the surface does not equal the evaporative demand, the surface dries and a parabolic water distribution develops within the soil.

Doorenbos and Pruitt (1977) gave a good explanation of the effect of available soil water on evapotranspiration. They stated that after irrigation or rain, the soil water content will be reduced primarily by evapotranspiration. As the soil dries, the rate of water transmitted through the soil will be reduced. When at some stages, the rate of flow falls below the rate needed to meet ET crop. It will fall below its predicted level. The effect of soil water content on evapotranspiration varies with crop and is conditioned primarily by type of soil and water holding characteristics. When evaporative conditions are lower, the crop may transpire at the predicted rate even though available soil water depletion is greater, when higher, ET crop will be reduced of the rate of water supply to the roots is unable to cope with transpiration losses. This will be more pronounced in heavy textured than in light textured soils.

In the light of the previous results, it can be concluded that evapotranspiration exhibited a great response to changes in soil moisture stress. It is high at low water suction and decreased rapidly at severe moisture stress.

4.1.3.1.2. Semi-Monthly Rates:

Semi monthly water use by onion plant under different levels of soil water after three seasons of study is presented in Table (11). Data clearly show that semi monthly rates of water use were lower at the beginning of the growing season then increased gradually by the development of onion plant.

The higher semi monthly values of evapotranspiration were recorded during March which represents the peak period of water demand by onion crop. This trend was found to be true in all levels of soil water. Such phenomenon can be explained on percent cover basis. Later on, a decline in evapotranspiration rate was observed when crop matured. These results are in line with those reported by Gates and Hank, (1967) who pointed out that most studies have shown a gradual increase in evapotranspiration from planting time to maturity, at which time evapotranspiration is equal to potential evapotranspiration. After maturation, evapotranspiration generally decreases. The gradual increase in evapotranspiration from planting to maturity can be discussed on the basis of percent cover.

As for the effect of water deficits on semi monthly water consumption, data in Table (11) indicate that an increase in soil moisture stress prior to irrigation did result in a significant decrease in semi monthly water use values. The reverse was found to be

TABLE (11): EFFECT OF WATER DEFICIT ON DAILY EVAPOTRANSPIRATION OF ONION (Bulb crop) DURING THE THREE SEASONS.

Daily evapotranspiration in mm/day										
Month	Nov	Dec	Jan	Feb	Mar	April	Daily ET			
Treatment	1-15	16-31	1-15	16-31	1-15	16-31	1-15	16-31	mm	
Season 1981/1982										
Wet (A)	1.47	1.39	1.74	1.76	2.44	3.46	4.35	3.99	2.67	2.48
Moist (B)	1.47	1.39	1.64	1.73	2.14	3.03	3.89	3.27	2.33	2.22
Medium (C)	1.47	1.27	1.37	1.57	1.85	2.66	2.94	2.51	2.21	1.89
Dry (D)	1.47	1.15	0.81	0.81	1.52	1.85	1.81	1.60	1.20	1.29
Season 1982/1983										
Wet (A)	1.28	1.62	1.46	1.82	2.83	3.10	4.09	3.63	2.25	2.45
Moist (B)	1.28	1.26	1.07	1.46	2.49	2.87	3.56	3.01	2.10	2.11
Medium (C)	1.28	1.12	1.00	1.45	1.72	2.45	2.63	2.33	2.04	1.77
Dry (D)	1.28	0.91	0.82	0.82	0.97	1.64	1.64	1.64	1.42	1.26
Season 1984/1985										
Wet (A)	1.47	1.46	1.62	1.62	2.57	3.33	4.29	3.88	2.37	2.46
Moist (B)	1.47	1.46	1.11	1.36	1.41	2.22	2.55	3.44	2.01	2.04
Medium (C)	1.47	1.46	1.08	1.25	1.25	1.99	2.08	2.41	2.01	1.75
Dry (D)	1.47	1.46	0.92	0.92	1.04	1.59	1.59	1.36	1.36	1.24

true. These findings are in agreement with **Eagleman and Decker (1965)** who concluded that water consumption increase depends on the increasing of soil moisture availability for plants.

4.1.3.1.3. Daily Rates:

The Daily evapotranspiration rates by onion plant during the period of study as influenced by soil moisture stress are presented in Table (12). As a general trend, results demonstrate that daily rates were low after transplanting onion seedling (December). Such pattern can be ascribed to that plant vegetation was not established yet and most of water loss is by evaporation. Thereafter, a gradual increase in daily values of evapotranspiration was observed as the plants grew up. This is mainly due to the growth of onion plant. The values of daily water use recorded their maximum during the first two weeks of March. These results may show that evapotranspiration rates stood parallel to the increase in plant vegetation as well as the increase in radiation and air temperature. A decline in water use rate was observed at maturation period of onion.

In this respect, **Harrold et al (1959)** concluded that evaporation was greater than transpiration early in the season when plants were small and intercept little of the net radiation. Later on, as the plant cover increased, transpiration was greater than evaporation

Table (12): EFFECT OF WATER DEFICIT ON MEAN DAILY EVAPOTRANSPIRATION OF ONION
(Bulb Crop) in mm/day.

Treatment	Relative growth period %									
	10	20	30	40	50	60	70	80	90	100
Wet (A)	1.40	1.43	1.49	1.70	2.21	2.94	3.87	4.00	3.13	2.37
Moist (B)	1.40	1.28	1.22	1.48	1.93	2.33	2.91	3.19	2.85	2.17
Medium (C)	1.38	1.12	1.23	1.43	1.86	2.21	2.53	2.42	2.16	2.02
Dry (D)	1.37	0.96	0.85	0.85	1.57	1.69	1.59	1.40	1.27	

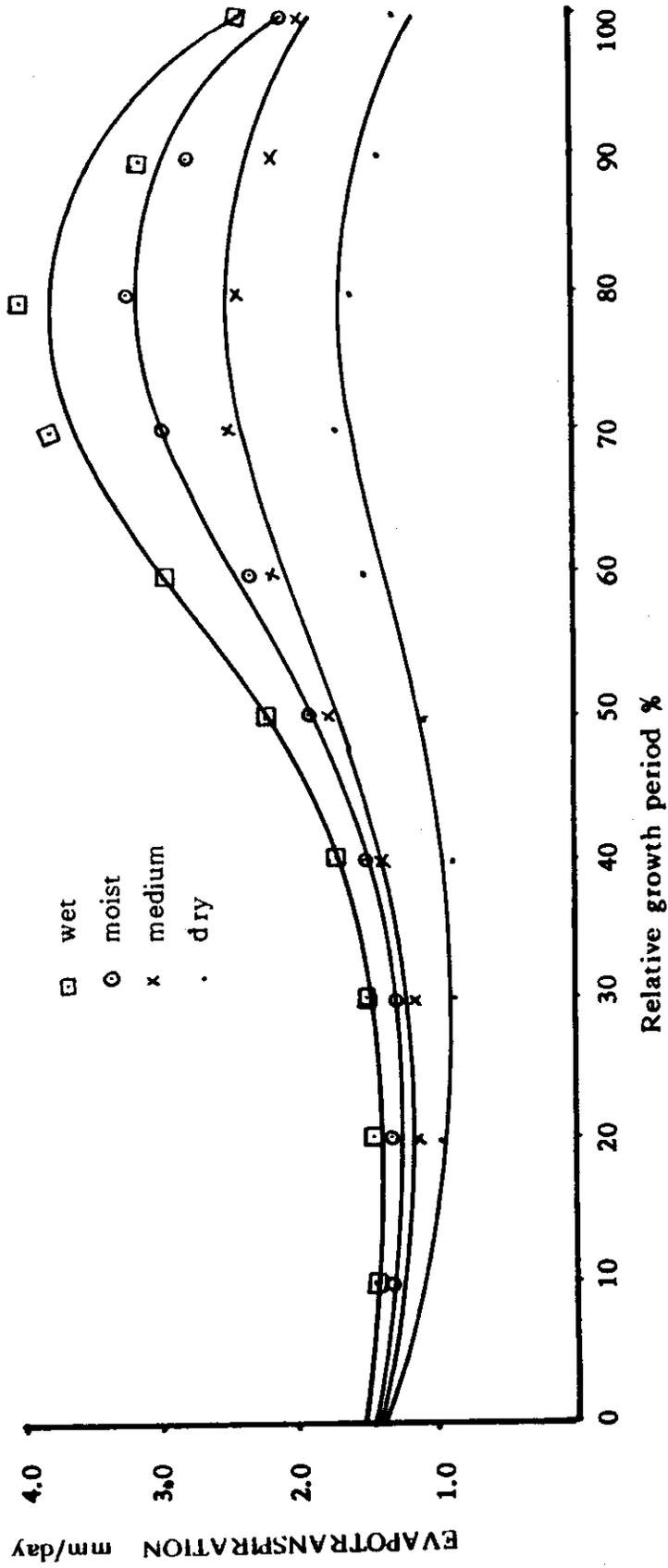


Fig. (8): DAILY EVAPOTRANSPIRATION OF ONION AS RELATED TO RELATIVE GROWTH PERIOD UNDER DIFFERENT SOIL MOISTURE LEVELS.

Lemon et al (1959) reported that the gradual increase in evapotranspiration from planting to maturity can be explained on the basis of percent cover. The decrease in evapotranspiration after maturation is probably a plant dependent factor. However, in most studies soil water is not maintained at a high level after maturation.

Soil moisture stress has a negative effect on daily evapotranspiration by onion plant. As soil moisture stress increased daily rate of water use by onion was decreased. This pattern of results is due to water availability to the plants. In this connection, Black (1965)

concluded that the independence of evapotranspiration and density of vegetation canopy exists for different reasons, where soil is dry than where water is available for evaporation and transpiration. Under moist conditions, the control is in the atmosphere. Under dry conditions, the control is in the soil. Under moderate conditions, the control may be partly in the soil and partly in the plants. Also, Russell (1975) stated that the drier the soil, the lower is the maximum rate that the roots can supply water to leaves.

A summary of the effect of water deficits on daily evapotranspiration by onion plant as related to its growth cycle (mean of the three seasons) is given in table (12) and illustrated in Figure (8). The data clearly show that the values started with very low amounts after transplanting, increased gradually as the plants grew up to

reach a maximum when plants complete 80% of their growth cycle then declined after that to a minimum value during harvest time. Soil moisture stress decreased such values in the corresponding growth periods but follow the same trend

Considering the pattern of daily water use by onion plant, it seems better to represent the data as continuous function relating the daly water use rate to the relative growth period in percentage. The most efficient function that gives the best description of daily water use of onion with respect to its growth cycle is the quadratic function in the form:

$$\hat{y} = a + bx + cx^2$$

Where, \hat{y} = daily evapotranspiration of onion in mm/day.

x = relative growth period as a percentage.

a, b, c are the parameters of the function.

The above mentioned function may demonstrate to what extent the growth cycle of the plant affects its daily water use rate. These equations predict the daily water use by onion at any specific period of its growth as well as the period of maximum demand for water. The latter point can be determined by differentiation and equating the derivative with zero.

The different functions obtained under the four moisture levels are:

1- Wet treatment:

(Irrigated after the depletion of 20% in available water).

$$\hat{y}_1 = 0.185 + 7.058x - 4.189 x^2$$

$$R^2 = 0.6670^{**}$$

2- Moist treatment:

(Irrigated after the depletion of 40% in available water).

$$\hat{y}_2 = 0.694 + 4.737x - 2.832 x^2$$

$$R^2 = 0.7028^{**}$$

3- Medium treatment

(Irrigated after the depletion of 60% in available water).

$$\hat{y}_3 = 0.4072 + 4.307x - 2.519 x^2$$

$$R^2 = 0.8419^{**}$$

4- Dry treatment

(Irrigated after the depletion of 80% in available water).

$$\hat{y}_4 = 0.329 + 2.695x - 1.606 x^2$$

$$R^2 = 0.7288^*$$

Statistical analysis had shown that the previous relations between daily water use and relative growth period of onion were highly significant at the three moisture levels i.e. wet, moist and medium and significant at 0.05 for the dry treatment. The variations between the parameters of these functions may show to what extent soil moisture stress affects the daily evapotranspiration by onion plant as well as the period of maximum demand to water.

4.1.3.2. Potential Evapotranspiration

Estimates of evapotranspiration are required in areas where no studies have been made or when local data are not available. The estimating procedure in use today is generally based on the correlation of measured with one or more climatic factors. Direct field measurements are very expensive and are mainly used to provide data to calibrate methods for estimating evapotranspiration from climatic data. The main thrust of research has been to determine the amount of water used for crop production and to develop methods of predicting evapotranspiration from climatic data.

The concept of potential evapotranspiration had been first introduced by Thornthwaite in 1944. He defined it as that water loss which occur if at no time there is a deficiency of water in the soil for the use of vegetation. Thornthwaite (1954) stated that it was necessary to specify a number of plant and climatic conditions in order to define potential evapotranspiration. However, the most important and widest use of the concept has been in the calculation of crop water requirements and it made the basis of a number of successful schemes of irrigation centre especially in humid regions.

Numer equations that require meteorological data have been proposed and several are commonly used to estimate evapotranspiration for periods of a day or more. These equations are all empirical to

various extents, the simplest requiring only average air temperature, day length. The generally better performing equations require daily radiation, temperature, vapour pressure and wind data. An attempt was made to estimate potential evapotranspiration by three methods i.e. Blaney and Criddle, Turc and Modified Penman.

Daily potential evapotranspiration rates on the basis of semi-monthly records of meteorological data during the three seasons are represented in Table (13). As a general, the values of potential evapotranspiration expressed as mm/day were low during December and January then increased gradually from February till May. This trend can be ascribed to the increase in air temperature as well as to the increase in total solar and sky radiation. The amount of radiation increased from 460 cal/day/cm^2 during December to 946 cal/day/cm^2 through May.

The results illustrated in Table (13) indicate that estimates of potential evapotranspiration by Blaney and Criddle were lower than those obtained from either Turc or Penman methods. This is mainly due to that it involves only two parameters, temperature (T) and percentage of day live hours (F) as a climatic factors to predict the effect of climate on evapotranspiration. The effect of climate on evapotranspiration is not fully determined by temperature and day length. Such modification done by Doorenbos and Pruitt (1977) was

found to be insufficient for the estimation of potential evapotranspiration. The previous findings are in line with those reported by Rijtema and Abou Khaled (1975) who concluded that Blaney and Criddle consumption use factor (F) insufficiently reflects the differences in agrometeorological conditions for crop water requirements.

With regard to the figures obtained by Turc method, they were lower than those from Penman method. Such results are expected owing to the fact that radiation may not be enough to get reasonable estimates of evapotranspiration. Also, the constant of the formula is not suitable for Mallawi region (Middle Egypt).

In this respect, Jensen (1966) pointed out that the major limitation of any empirical equation for estimating evapotranspiration is that its constant may not be applicable in other regions without calibration. Also, Abd El-Hamid et al (1985) concluded that for better use of Turc formula, the constant must be changed from 0.0133 to 0.017.

It can be mentioned that the use of Penman's method is preferred as it offers the possibility of analysing the relative importance of the various climatic factors in determining the rate of water use under non-limiting soil moisture conditions. In this connection, Aslyng (1961) showed that the effect of wind-breaks in reducing evaporation could be accurately calculated from Penman's formula.

Stanhill (1961) concluded that the methods with a sound theoretical basis i.e. open water surface evaporation calculated by Penman's method or measured with a standard surface are the most satisfactory whilst the empirical methods are either inaccurate or require considerable correction. Abd El-Hamid et al (1985) pointed out that modified Penman method offer a good and reliable estimate of potential evapotranspiration. On the other hand, Tawadros et al (1979) reported that correlation studies between actual and estimated values of evapotranspiration showed a significant relationship. Blaney and Criddle formula gave best estimates for crops grown in Upper Egypt, while, modified Penman gave lower values than those obtained by Blaney and Criddle.

For empirical purposes, simplicity and cost suggest that the use of Turc method for estimating evapotranspiration at Mallawi region can be accepted with less accuracy.

4.1.3.3. Crop Coefficient (Kc)

Since most crops do not require as much water during the season as would be needed to meet potential evapotranspiration, the term crop coefficient has been developed to reflect the physiology of crop, the degree of crop cover on the potential evapotranspiration. Such term is calculated as the dimensionless ratio of crop evapotranspiration and potential evapotranspiration.

Doorenbos et al (1979) defined the stages in onion development as follows:

- 1- Initial stage: From transplanting to 10% ground cover. (15-20 days).
- 2- Crop development stage: From 10% to 80% ground cover (25-35 days).
- 3- Mid season stage: From 80% ground cover to start of ripening (25-45 days).
- 4- Late season stage: From start of ripening to harvest (35-45 days).
- 5- Harvest: From the end of late season stage to the time of harvesting. (5 - 10 days).

The crop coefficient of onion throughout its growth cycle is presented in Table (14). The values were calculated according to the daily potential evapotranspiration estimated by either Penman method or Turc formula and the actual evapotranspiration derived from the wet treatment considered as the treatment when water is not limiting).

Crop coefficient was low at the initial stage (0.60) due to less vegetation cover. Then Kc increased as the crop cover increased to reach a maximum during the mid and late season stages. Such periods are considered as the peak water demand by onion crop. Therefore, crop coefficient decreased (0.30 - 0.43) again when the crop reached

Table (14): CROP COEFFICIENT OF ONION PLANT (bulb crop) BY TURC AND PENMAN METHODS AT VARIOUS STAGES OF ITS GROWTH.

		ONION BULB CROP STAGES					Seasonal
		initial stage	Development stage	Mid season stage	Late stage	Harvest stage	
Actula evapotranspiration (Wet treatment)		1.40	1.46	2.28	3.66	2.37	367.92
Potential:							
	Turc	2.33	2.18	2.52	3.97	5.50	474.90
	Penman	2.49	2.38	2.99	5.22	7.40	589.20
K.C.							
	Turc	0.60	0.67	0.90	0.92	0.43	0.77
	Penman	0.56	0.61	0.76	0.70	0.30	0.62

maturity. It is worthy to mention that seasonal onion crop coefficient was 0.77 and 0.65 respectively for Turc and Penman methods.

The previous results were explained by Jensen (1968) who concluded that seasonal evapotranspiration for most common farm crops will be less than the potential because the soil may be completely bare for some time prior to planting, leaf area is limited as the seedling emerge and develop, and the effective resistance to transpiration increases as the crop begins to mature. Erie et al (1965) at Arizona U.S.A. found that seasonal crop coefficient of dry onion was 0.80.

4.1.4. Water uptake by onion roots

Moisture removal from the soil profile has been used to evaluate the rooting characteristic of different plant species. Russell and Danelson (1956) concluded that the supplement of water derived either from irrigation or rainfall affects only the upper two feet of soil moisture. However, Bennett and Doss (1960) pointed out that soil moisture extraction pattern can be used with reasonable accuracy for estimating the effective rooting depths of several plant species. Bethlahmy (1963) stated that water is removed from soil by roots where effect on soil moisture variation is probably related to their concentration.

The changes of soil moisture in some irrigated farms in Egypt has been a subject of investigation, for many years. In these researches it has been proved that the cyclic changes in soil moisture take

place almost in the top 50 cm of soil profile (El-Shal, (1953), Zein El-Abdine et al (1962); Abd-El-Warith (1965).

Seasonal storage of water in the soil and differential extraction according to irrigation treatments through the period of study are presented in Figure (9). The data clearly show that onion plant extracted more than 50% of its moisture need from the first layer i.e. 0 - 15 cm. Less values were removed from subsequent layers. The least value of water uptake compared to the other layers was from the fourth one i.e. 45 - 60 cm. From such layer, onion plant extracted less than 10% of the water need. The previous results were found to be true in the three seasons irrespective to irrigation treatments. These results are in agreement with those reported by Russell (1961) and Feeds and R tma (1972) who concluded that the relative high water uptake from the top layers compared to deep layers is the result of the concentrated roots in the upper layers.

Concerning the influence of soil moisture stress on water uptake from the successive layers, the data showed that increasing soil moisture stress did result in an increase in moisture removal from deeper layers. In other words, increasing soil moisture stress prior irrigation increased the percentage of moisture extracted by onion roots from the third and fourth layers i.e. 30 - 45 and 45 to 60 cm. These findings may prove that when soil is kept wet by frequent irrigations, more water is extracted from the upper layers. These results are in line with those reported by Israilsen and Hansen (1962) who concluded that in arid regions more water is extracted from the first foot of soil, wherever it is kept moist by irrigations.

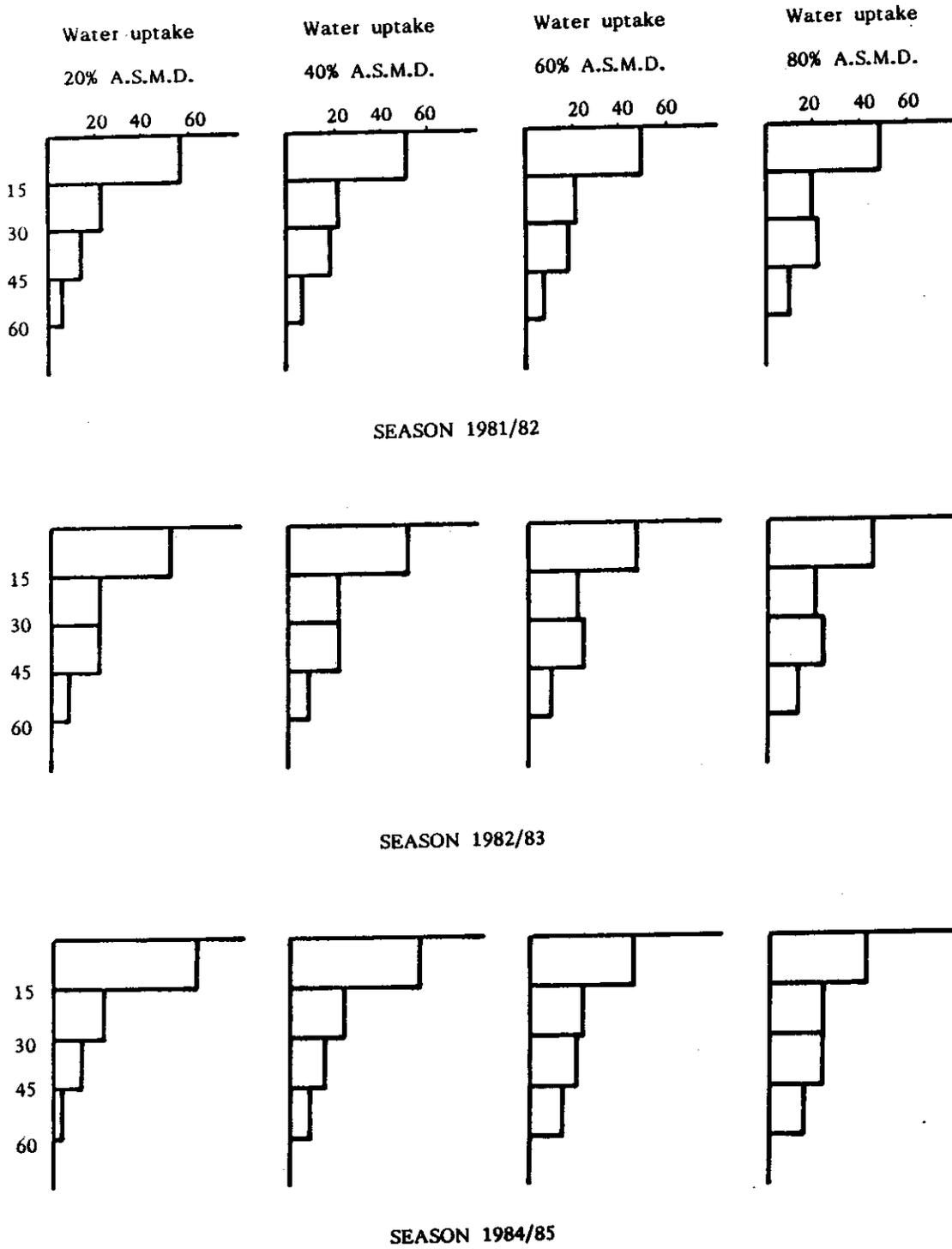


Fig.(8): WATER UPTAKE BY ONION (Bulb Crop) AS AFFECTED BY AVAILABLE SOIL MOISTURE DEPLETION (A.S.M.D.) SEASONS 1982, 1983, and 1985

Russell and Danielson (1956) stated that as the surface soil is reduced in water content fertility, the plant with an extensive root system may continue to meet nutrient and transpirational demands from greater depths. Thus the interval between irrigations and fertilizer applications can be extended, Efficiency is increased, and the natural fertility of the sub soil may be utilized.

4.1.5. Water and Onion Yield Relations:

The use of water balance as a tool for estimating soil moisture is not the accurate method for intelligent irrigation. The problem is the understanding of the relationship between water and yield in order to obtain the maximum production. Adequate application of water to meet transpiration needs will not only ensure rapid leaf development at young stages but also maximum photosynthesis when the crop has reached optimum leaf area. index.

Chang (1971) concluded that when the actual evapotranspiration falls short of the potential, the actual yield will also be less than the maximum. However, the relationship between evapotranspiration and yield in the field may or may not be linear as it is between transpiration and dry matter production in container experiments. This is partly because the fraction of evaporation that does not contribute to plant growth varies throughout the crop life cycle.

The study has been extended to find out the relation between onion yield (bulb crop) and either water deficit or evapotranspiration. The following relationship has been determined:

1- Water deficit and onion yield.

The results of the three experiments has been analyzed by plotting the total bulb yield of onion against the retained soil moisture prior irrigation. The relation estimated has the curve shape. The best description of this relation was found to be the quadratic function in the form:

$$\hat{y} = a + bx + cx^2$$

Where

\hat{y} = onion yield in tons/feddan

x = the retained available soil moisture prior irrigation in percentage.

a, b, c are the parameter of the function.

a- The function obtained for total bulb yield was as follows:

$$\hat{y} = 3.832 + 20.52x - 16.88 x^2$$

$$R^2 = 0.0875^*$$

Such relation was statistically significant. By differentiation and equating the derivative with zero, maximum onion yield with respect to the level of soil moisture level can be obtained:

$$dy/dx = 20.52 - 33.76 x$$

$$x = (20.52/33.76) = 0.61$$

This means that the level of soil moisture for irrigating onion (bulb production) to ensure higher production is when 39% of available soil moisture is depleted or 61% from available water remained in the soil profile. Such results indicate the importance of soil water to ensure higher bulb yields.

b- The function obtained for exportable onion yield was as follows:

$$\hat{y} = 3.290 + 19.97x - 18.03 x^2$$

$$R^2 = 0.0753$$

Such relation was found to be insignificant.

By differentiation, maximum exportable onion yield with respect to water deficit can be obtained :

$$dy/dx = 19.97 - 36.06 x$$

$$x = 0.55$$

The previous relation may show that the best level of soil moisture to irrigate onion in order to produce maximum exportable bulb yield is when 45% of available soil water is depleted.

It can be concluded from the previous results and Figure (10) that soil water is an important factor in determining the bulb yield of onion. The best level of water deficit to obtain higher or maximum

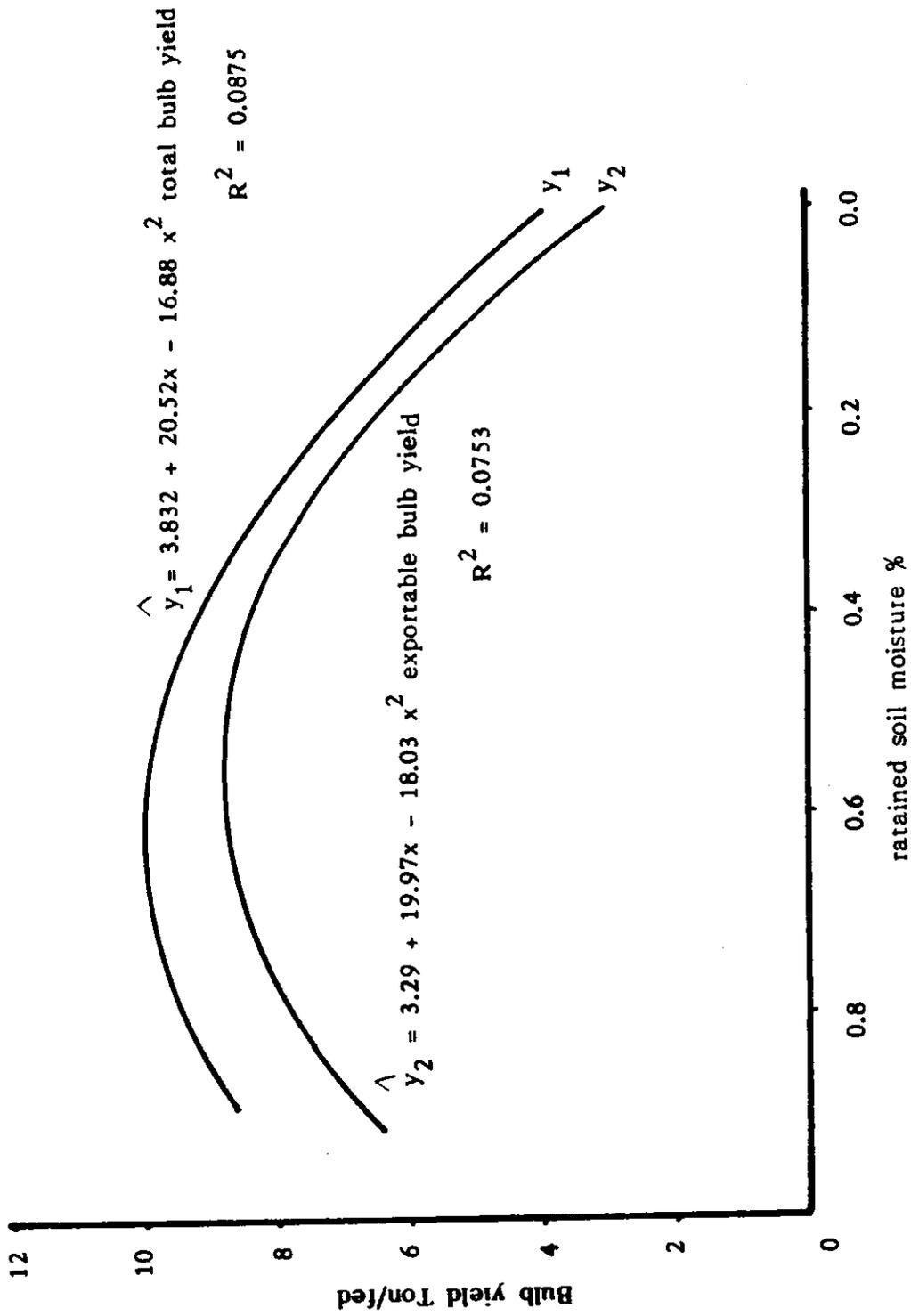


Fig.(10) : WATER DEFICIT AND ONION BULB YIELD RELATIONSHIP

bulb production is 40 - 45% depletion in available soil moisture. This level has been proved to ensure maximum production either as total bulb yield or as exportable bulbs. In this respect Chang (1971) concluded that some crops grow best under high soil moisture others require a good aeration for maximum productivity.

2- Water use and onion yield

Another factor that must be considered in the relationship between water and crop yield is the water use and yield function. The relationship between water and onion yield has been established from field yield data of the these irrigation experiments. Such approach is preferred not only because it minimizes the number of variables, but also because it can be set up in a way as to encompass a wide range of moisture treatments. Seasonal evapotranspiration have been plotted against onion yield either total or exportable bulbs. The quadratic function was found to be the best type of such relationship the same as observed with water deficit. Analysis of the variance proved that these two relationships i.e. with total bulb yield or exportable yield were significant at 5% level. The obtained functions are graphed in Fig. (11) and as follows:

a- Total bulb yield:

$$\hat{y} = - 6.683 + 1.097x - 0.0182 x^2$$

$$R^2 = 0.0956$$

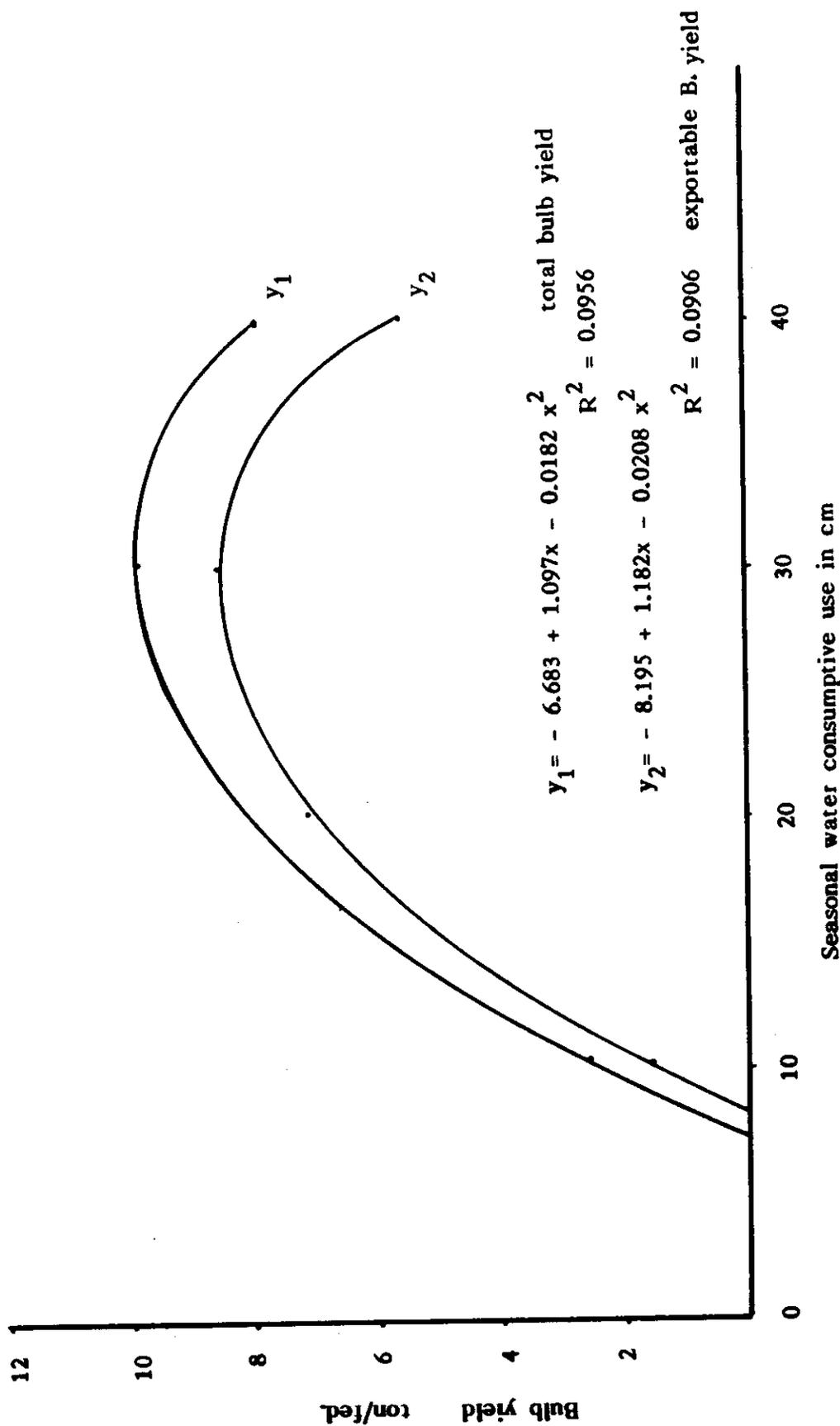


Fig.(11): SEASONAL EVAPTRANSPIRATION AND BULB YIELD

where y = total bulb production in tons/fed.
 x = seasonal water consumption in cm.

Differentiating the above function, seasonal evapotranspiration that produce maximum bulb yield can be obtained:

$$\begin{aligned} dy/dx &= 1.097 - 0.0364x \\ x &= (1.097/0.0364) = 30.14 \text{ cm} \end{aligned}$$

b- Exportable bulb yield:

$$\begin{aligned} \hat{y} &= - 8.195 + 1.182x - 0.0208 x^2 \\ R^2 &= 0.0906^{**} \end{aligned}$$

where y = Exportable bulb yield in tons/fed.
 x = Seasonal water consumption in cm.

By differentiation, seasonal water use that yield the maximum production is obtained:

$$\begin{aligned} dy/dx &= 1.182 - 0.0416x \\ x &= (1.182/0.0416) = 28.41 \text{ cm} \end{aligned}$$

The preceding functions described the relation between water use and bulb production by onion. It can be concluded that onion plant consumed from 28.4 to 30.14 cm water to produce the maximum bulb yield. The yield of onion is more related to evapotranspiration.

4.1.6. Water use efficiency:

As irrigation water supplies become more limited or as water costs increase in an area, the management objective may shift to optimizing production per unit of applied water. Efficiency of water use in terms of units of water used per unit of dry matter produced is important. In general the higher the yield of dry matter the higher the efficiency, because dry matter production increases more rapidly than water loss. Water use efficiency can be increased either by increasing crop productivity or by decreasing losses due to evapotranspiration.

4.1.6.1. Dry matter production:

A summary of water use efficiency at various stages of onion growth expressed as Kg. dry matter produced/m³ of evapotranspiration under different soil moisture levels is presented in Table (15). Data clearly show that water use efficiency was lower early in the season (60 days after transplanting). Then increased to a maximum value when plants aged 90 days. Therefore, water use efficiency rededcreased again to a minimum value when plants started to mature (120 days after transplanting). Such type of results may indicate the importance of water supply through the period of building up onion bulbs (90 days after transplanting) as water utility showed its maximum rate.

Table(15): EFFECT OF WATER DEFICIT ON WATER USE EFFECIENCY OF ONION BULB THROUGHOUT ITS GROWTH CYCLE Kg.dry matter/m³ seasons 1981/1982 and 1982/1983.

	60 days	90 days	120 days
Season 1981/1982			
Wet (A)	1.42	1.91	1.14
Moist (B)	1.46	1.84	1.29
Medium (C)	1.55	2.08	1.46
Dry (D)	1.72	2.24	1.60
Season 1982/1983			
Wet (A)	1.11	2.01	1.45
Moist (B)	1.17	1.86	2.13
Medium (C)	1.21	2.23	2.41
Dry (D)	1.25	2.35	2.27

The lower values of water use efficiency in the first period can be discussed on the fact that when plants are very small, they intercept little of total radiation received. Also, the evaporation rate is high from the exposed soil surface. The maximum water use of efficiency at the period of bulb formation may be related to that onion plant attained its highest vegetation growth through such period. Later on, the decrease in water use efficiency is probably due to maturation. The previous results are in full agreement with those reported by Ritchie and Burnett (1971) who concluded that water use efficiency was extremely low at the beginning of the growing season and increased gradually to a maximum during the period of rapid vegetative growth.

With regard to the role of soil moisture stress on water use efficiency by onion during its growth cycle, data presented in Table (15) revealed that it seemed to increase by increasing soil moisture stress. The reverse trend was found to be true. These results was the same in the two seasons and can be ascribed to less dry matter produced per unit of water consumed under frequent irrigations then under prolonged ones. These results are in line with those reported by Vites (1965) who concluded that water use efficiency is not closely dependent on the water available if the supply is within the evapotranspiration limit, even though the crop yields and the opportunity to increase crop yield depend on the adequacy of the water supply,

particularly for crops such as forage, where the total dry matter is harvested.

4.1.6.2. Marketable Yield:

Table (16) represent the effect of soil moisture stress on water use efficiency expressed as bulb yield/one m^3 of water consumed. Soil moisture stress induced a great response upon water use efficiency values. Statistical analysis showed that different levels of water deficit induced a highly significant effect on water use efficiency by onion in the three seasons of study. This pattern was found to be true when the numerator was total bulb yield or exportable bulbs. This finding may prove that water use efficiency was greatly affected by soil moisture stress.

Mean water use efficiency values for exportable bulb yield were 5.95, 7.21, 9.24 and 9.39 Kg. of bulbs evapotranspiration in m^3 for wet, moist, medium and dry soil moisture levels respectively. It is clear that maximum values were gained from the medium and dry soil moisture levels without any significant differences among them. The lowest value was produced from the wet treatment, while the moist treatment produced an intermediate value. These results show that water use efficiency increased as soil moisture stress increased. The differences between wet

Table (16): EFFECT OF WATER DEFICIT ON WATER USE EFFICIENCY Kg BULBS/CUBIC METER DURING THE PERIOD OF STUDY.

Treat	Exportable yield Kg/m ³				Total yield Kg/m ³				
	season	season	season	season	mean	season	season	season	mean
	1981/82	1982/83	1984/85	1981/82	1982/83	1984/85	1981/82	1982/83	1984/85
Wet (A)	5.61	6.80	5.43	6.68	5.95	8.06	6.49	7.08	
Moist (B)	6.60	7.97	7.06	7.53	7.21	9.46	8.09	8.36	
Medium (C)	8.51	10.04	9.16	9.05	9.24	10.88	10.04	9.99	
Dry (D)	9.97	9.51	8.69	10.62	9.39	10.96	9.83	10.47	
Sign. levels	**	**	*	**	**	**	**	**	**
L.S.D.	0.47	1.36	0.60	0.43	1.37	0.66			

and moist soil moisture levels and the rest of the treatments were found to be significant. Also, the wet and moist treatments differ significantly with respect to water use efficiency. It can be concluded that water use efficiency by onion expressed as total bulb production per one cubic meter of water consumed in complete evapotranspiration was higher under dry conditions and decreased as soil moisture maintained high.

The previous results could be explained by considering the relative decrease in bulb yield and evapotranspiration due to the increase in soil moisture stress. As soil moisture stress increased a reduction in onion bulb yield was observed. However, the reduction in evapotranspiration due to water deficit was found to be much more than the decrease in bulb yield which did result in a higher water use efficiency values. In this respect, Vites (1965) summarizing water use efficiency data concluded that no generalization can be made about water use efficiency as related to available water supply. He added that the seasonal evapotranspiration and the yield are an integration of many factors such as plant cover and soil moisture stress.

With regard to total bulb yield, mean water use efficiency values were 7.08, 8.36, 9.99 and 10.47 Kg bulbs/one cubic meter of water consumed. for wet, moist, medium and dry treatments respectively

Results reveal that water use efficiency increased as soil moisture stress increased. The same trend was found to be true in the three seasons. Results are similar to those obtained with exportable bulb yield of onion. However, the dry treatments produced the maximum value of water use efficiency in two seasons only. It can be mentioned that, water use efficiency was greater under severe soil moisture stress and decreased by decreasing soil moisture tension prior irrigation. In this connection, Ritiche (1974) pointed out that some water conservation benefits can be derived from allowing plants to experience moderate water stress. It is well known that plant roots extract soil water from greater depths than plants kept irrigated to optimum levels. Thus, water stored in the profile is used more efficiently.

4.1.7. Chemical Composition:

4.1.7.1. Percentage and content of nitrogen

It can be generally noticed from Tables (17 and 18) that nitrogen percentage in different parts decreased gradually till it reached the lowest value after 120 days from transplanting in both successive seasons. Different parts of onion plants in 1982/1983, season have mostly higher nitrogen percent than those grown during 1981/1982 season. It was found that there is not clear differences between different water deficit treatments. Concerning leaf blade,

Table (17): EFFECT OF WATER DEFICIT ON N% OF DIFFERENT PLANT PARTS OF ONION (bulb crop) AT SUCCESSIVE PERIODS OF GROWTH AND BULBS AFTER CURING (season 1981/82 & 1982/83)

Plant age	60 days			90 days			120 days			after curing
	leaf blade	leaf base	leaf blade	Neck	bulb	leaf blade	Neck	Bulb	Bulbs	
Season 1982										
Wet (A)	3.5	2.00	3.30	1.60	1.80	2.50	1.50	1.50	1.40	
Moist (B)	3.6	2.05	3.40	1.70	1.80	2.50	1.55	1.50	1.50	
Medium (C)	3.6	2.10	3.50	1.70	1.85	2.50	1.60	1.50	1.60	
Dry (D)	3.7	2.15	3.65	1.75	1.90	2.60	1.65	1.60	1.75	
Season 1983										
Wet (A)	4.2	2.70	3.60	2.05	2.20	3.00	1.65	2.00	1.60	
Moist (B)	4.1	2.65	3.50	2.05	2.30	3.0	1.55	2.00	1.70	
Medium (C)	4.0	2.65	3.50	2.10	2.30	3.10	1.60	2.00	1.75	
Dry (D)	4.1	2.65	3.60	2.25	2.40	3.2	1.75	2.15	1.80	

data showed that it mostly has higher nitrogen percent than neck or bulb during different stages of growth.

With regard to water deficit treatments, they seem to have no obvious effect on nitrogen concentration in idfferent plant parts. As for the differences between the data of the two seasons, they may be related to the variation of soil nitrogen content and different enviornmental conditions.

A very slight increase in nitrogen percent of bulbs after curring was observed by decreaseing soil moisture deficit which may indicate that water deficit could have an effect on notrogen acculation in bulb after curring.

The unclear effect of water deficit treatments on the concentration of nitrogen in idfferent onion plant organs lead- ing us to extend our results to the total absorption of nitrogen per plant. It could be concluded that total nitrogen content increased gradually in different parts of onion plant as well as the whole plant during successive periods of growth. This may indicate the continuous absorption of nitrogen during the whole period of growth. It can be seen wet treatment stimulated such absorption followed by a continuous decrease in nitrogen absorption

Table (18): EFFECT OF WATER DEFICIT ON NITROGEN CONTENT OF DIFFERENT ORGANS OF ONION PLANT AT SUCCESSIVE PERIODS OF GROWTH AND THE BULBS AFTER CURING IN mg (Season 1981/1982 and 1982/1983)

Plant age	60 days				90 days				120 days				after curing	
	leaf blade	leaf base	total N content	leaf blade	neck	bulb	total N content	leaf blade	Neck	bulb	Total N content	Total N content	Total N content	
Season 1981/82														
Wet (A)	92.40	27.60	120.00	110.55	51.68	36.36	198.59	147.75	79.95	79.65	307.35	172.43	172.43	
Moist (B)	82.80	33.00	115.80	109.14	48.62	33.12	190.88	142.50	79.67	77.70	299.87	181.56	181.56	
Medium (C)	68.76	38.01	106.77	109.55	48.62	31.45	189.62	141.00	75.68	76.65	293.33	190.08	190.08	
Dry (D)	67.34	30.53	97.87	97.45	41.65	22.42	161.52	118.04	59.40	66.40	243.84	178.32	178.32	
Season 1982/1983														
Wet (A)	61.74	48.60	110.34	90.72	72.77	52.80	216.29	165.56	91.08	104.60	361.24	152.96	152.96	
Moist (B)	56.58	37.63	94.21	81.90	59.45	44.16	185.51	174.60	89.28	106.00	369.88	168.81	168.81	
Medium (C)	48.80	40.54	89.34	75.60	52.92	49.68	178.20	160.89	82.56	96.00	339.45	160.47	160.47	
Dry (D)	36.90	34.71	71.61	51.84	35.10	44.08	131.02	116.48	54.60	71.81	242.89	155.16	155.16	

with increasing soil moisture stress.

The same trend was observed during both seasons of growth i.e. 1981/82 and 1982/83. However, total amounts of nitrogen in different plant parts in 1982/83 season were higher than the corresponding ones of the first season, and that may be related to the differences of environmental condition of both seasons. It may be concluded also that leaf blade accumulated the highest values of total nitrogen followed by neck, while bulb ranked the third in this respect during the first 90 days. Table (18)

After curing bulbs showed a higher total nitrogen than bulbs of 120 days old. This is related to the translocation of nitrogen from leaf blade and neck into bulb during curing period, which indicates that curing is essential for the accumulation of nitrogen in bulb and that is very important for increasing the nutritive value of the bulbs.

4.1.7.2. Percentage and content of phosphorus

Data in table (19) indicate that leaf blade have a higher concentration of phosphorus followed by the bulb and neck ranks the third, in this respect during all periods of growth. It could be mentioned also that the concentration of phosphorus decreased continuously in different plant organs during successive periods of growth. This may be related to the activity of the greater rate of dry matter accumulation in such organs than the rate of N uptake which resulted into a dilution of such element

in plant tissues. It could be noticed that soil moisture stress affected very slightly the concentration of phosphorus in different plant tissues. After curing a very slight increase in phosphorus concentration was observed and this may be related partially to loss of water from bulbs during curing or may be related partially to the translocation of phosphorus from leaf blade and neck into bulb.

With regard to phosphorus content, it may be concluded from Table (20) that leaf blade has the greatest total phosphorus content followed by the neck at 90 days only, while bulbs rank the third during this period. However, bulbs rank the second at 120 days; and the neck ranks the third in this respect.

After curing bulbs have higher amounts of total phosphorus than those of 120 days. This is related to the translocation of phosphorus during curing period from leaf blade, neck, and roots which were not analyzed. This indicates that curing period is very important for ripening of bulb. The higher increase of phosphorus in bulbs and the stable content in leaf blade and the decrease of phosphorus in neck indicate that phosphorus is translocated mainly from neck into bulb during the last period of growth (from 90 - 120 days). Soil moisture affected greatly the total amount of phosphorus in onion plant organs during

Table (20): EFFECT OF WATER DEFICIT ON PHOSPHORUS CONTENT OF DIFFERENT PLANT PARTS OF ONION (bulb crop) AT SUCCESSIVE PERIODS OF GROWTH AND BULBS AFTER CURING IN mg (Season 1981/82 and 1982/83)

Plant age	60 days				90 days				120 days				After curing
	leaf blade	leaf base	Total P content	leaf blade	Neck	Bulb	Total P content	Leaf blade	Neck	Bulb	Total P content	Total P content	
	Season 1981/82												
Wet (A)	9.24	3.17	12.41	9.72	5.23	3.33	18.28	9.16	5.33	6.37	20.86	23.04	
Moist (B)	8.05	3.70	11.75	9.31	4.63	3.04	16.98	8.83	5.14	6.22	20.19	22.63	
Medium (C)	5.73	4.16	9.89	8.76	4.63	2.72	16.11	8.74	4.73	5.11	18.58	20.19	
Dry (D)	5.46	3.27	8.73	7.48	3.69	1.89	13.06	6.54	3.60	4.15	14.29	16.81	
	Season 1982/83												
Wet (A)	5.88	5.22	11.10	8.82	7.45	5.04	21.31	11.59	8.56	8.89	29.04	18.93	
Moist (B)	5.52	4.11	9.63	8.19	5.80	4.03	18.02	12.22	8.93	9.01	30.16	19.66	
Medium (C)	4.88	4.44	9.32	7.56	4.79	4.54	16.89	10.38	7.43	7.92	25.73	17.33	
Dry (D)	3.51	3.80	7.31	4.32	2.96	3.84	11.12	7.28	4.49	5.18	16.96	16.29	

different periods of growth. The continuous decrease of total phosphorus in different plant organs at the successive periods of growth was observed with decreasing soil moisture content, indicating that variation of moisture content affected the absorption of phosphorus.

It can be noticed that the physical and biochemical activity of living organisms are subjected to the influences of their external and internal environments.