Growth and yield response of pot -grown shallots to water stress in a glasshouse experiment

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SUMMARY

Severe edaphic stress adversely affects the general performance of shallots (*Allium cepa* L. var. *ascalonicum* cv. Tropix.) This study was conducted to determine the effect of water stress on the growth and yield of shallots under 12-h daylength. Pot-grown shallots in a glasshouse were subjected to four levels of water stress, viz., flooded, regular watering, and watering up to half and quarter the field capacity (pot water-holding capacity = 373 g) of the root medium. Flooded shallots recorded the highest growth rate, leaf area, and green leaf number. Regularly watered and flooded shallots had the highest relative water contents of leaf tissue. Number of bulbs and axillary buds were not significantly ($P>0.05$) different in all the treatments despite the stress. The highest harvest index and bulb yield were, however, obtained in the regularly watered shallots. Water stress, thus, adversely affected shallot growth, maturation, and bulb yield under 12-h photoperiod, although tissue water content was relatively high.

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RÉSUMÉ

ABBEY, L. & FORDHAM, R.: *La réaction en croissance et en rendement d' échalotes plantées-en-pot contre la tension d' eau d' une expérience de serre.* La tension édaphique sévère influence défavorablement la performance générale d'échalotes (*Allium cepa* L.var *ascalonicum* cv. Tropix). Une étude était conduite pour déterminer l'effet de la tension d'eau sur la croissance et le rendement d'échalotes sous 12-heurs toute la journée. Les échalotes plantées -en-pot dans la serre étaient exposées à quatre niveaux de la tension d'eau c'est-à-dire, inondée, arrosage régulier, arrosage jusqu' à la moitié, et arrosage jusqu' au quart de la capacité du terrain (la capacité de la tenue d'eau du pot = 373g) de milieu radical. Les échalotes inondées enregistraient les plus élevés de proportion de croissance, superficie de feuille et nombre de feuille verte. Les échalotes régulièrement arrosées et inondées avaient les contenus d' eau relatifs les plus élevés du tissu de feuille. Nombre de bulbes et de bourgeon axillaire n'étaient pas considérablement ($P>0.05$) différents dans tous les traitements malgré la tension. L' indice de moisson et le rendement les plus élevés étaient, toutefois, obtenus dans les échalotes regulièrement arrosées. La tension d'eau donc, influençait défavorablement la croissance d' échalote, la maturité et le rendement de bulbe sous 12-heure de photopériode bien que le contenu d'eau du tissu soit relativement élevé.

Introduction

Shallot cultivation is favoured in the warm tropical regions of the world due to its bolting resistance as well as to its local disease resistance. Tummy (1992) reported shallot yield of 9 to 12 t/ha in Ghana. Sinnadurai (1971) observed that shallot production on sandy soils, as done in Anloga, near Keta in the Volta Region of Ghana, did not yield more than four times the quality planted as compared to a yield of about eight times what was planted which was observed in sandy-loam soils.

Inasmuch as the seasonal differences in daylength are rather small in the tropics, bulb and inflorescence development may be favoured by day/night temperature differences, and to a lesser extent by photoperiodicity (Uzo & Currah, 1990).

The efficiency with which absorbed light of a leaf canopy is converted to harvestable material can be affected by temperature and water status of the leaves (Salisbury & Ross, 1992). Typically, onions are plants of open, sunny, dry areas whose rates of transpiration, photosynthesis, and growth are affected by mild degree of water stress (Brewster, 1994). Levy *et al.* (1981) reported that onions survived long periods of water stress by remaining dormant, and recovered when they were irrigated. Periodic stress, followed by irrigation, could thus affect the smooth and consistent growth, as well as development and bulbing of onions.

In Ghana, shallots are grown in the major rainfall season from April to August. Bulb yield during this period is lower than in the minor growing season, i.e. dry-sunny season from January to March during which hand irrigation is used (Sinnadurai, 1973). Similar results have been reported in Nigeria (Denton & Ojeifo, 1990) and in Indonesia (Van der Meer & Permadi, 1990). Waterlogging also caused stressful conditions in shallots, especially during the peak rainfall season, and under poor water management practices as found in some farmers' field in Anloga (Sinnadurai, 1973).

This study therefore examined the extent to which shallot production is affected by different forms of water stress in Ghana.

Materials and methods

Two shallot (cv. Tropix) seeds were sown in each of the 190 plastic pots (9-cm diameter) placed in saucers in a glasshouse on 5th March 1995 at Wye College, University of London, UK. They were thinned to one seedling per pot 2 weeks after germination. Plants were subjected to 12-h photoperiod at average maximum and minimum temperatures of 31 and 16 °C, respectively, to simulate tropical conditions. This was done by using black polythene sheet hanged on a 2-row wire trellis 1.2 m above the bench on which the pots were placed. Whenever daylengths were more than 12 h, the polythene sheet was drawn to cover the potted plants, thus creating darkness. During short-day periods, i.e. less than 12 h, the plants were illuminated with 60-W incandescent lamp at a spacing of 1.5 m. The root medium used was peat mixed with grit in the ratio 4:1 at a *p*H of 6.5. Pot water-holding capacity (PC), permanent wilting point (PWP), and available water content (AWC) were 373, 224, and 149 g, respectively.

The experiment was laid in a complete randomized design with four replications (12 plants per treatment). The treatments were as follows: i) regular watering up to 100 per cent AWC as and when necessary; ii) watering up to 50 per cent AWC every 3 to 5 days; iii) watering up to 25 per cent AWC every 5 to 7 days; and iv) submerging potted plants in a bowl of water 2 cm above the pot surface (flooding) for the first 2½ months of growth, followed by regular watering. Water contents were assessed by weighing the pots on a balance and the loss of water determined by using the PC as a base. Fresh weights of the plants which add extra mass to the pot were determined on a monthly basis, and these were used to adjust watering. The potted plants were re-arranged periodically to minimize the effect of spatial variation in microclimate within the glasshouse. Observations were made on four randomly selected plants per treatment.

The data taken before final harvest covered the following: green leaf number; plant growth rate (leaf elongation per unit time) recorded by tagging a leaf of about 5 cm long and measuring the increment in length for 10 consecutive days; leaf area was obtained by measuring the length and maximum diameter of each green leaf of the sample plant, and the product multiplied by a factor of 2.22 (Weerasinghe, 1994); and number of lateral branches. Relative water content (RWC) was determined by cutting 2-cm length of a 0.5-0.6-cm diameter leaf from the middle portion. The fresh weight was quickly taken with a Metler digital balance. The piece of leaf was then dissected, floated in 52-ml distilled water, and exposed to light at room temperature for 6 h. The saturated weight was recorded after drying the leaf surface with Whatman A4 filter paper. The piece of leaf was then oven-dried at 45 °C for 18 h to constant weight. The RWC was calculated by determining the ratio of the water content of the leaf piece before and after saturation, and multiplying the result by 100 according to Catsky (1963), Slavik (1974), and Slatyer & Barrs (1965).

At final harvest, i.e. 80 per cent topfall, fresh and dry weights of shoot, bulb, and root were recorded. The number of axillary buds was recorded by dissecting the bulb under a dissecting microscope. Harvest index, number of bulbs per plant, and bulb weight and yield were also determined. Miitab for Windows release 9.2 (1993) was used to analyze the data.

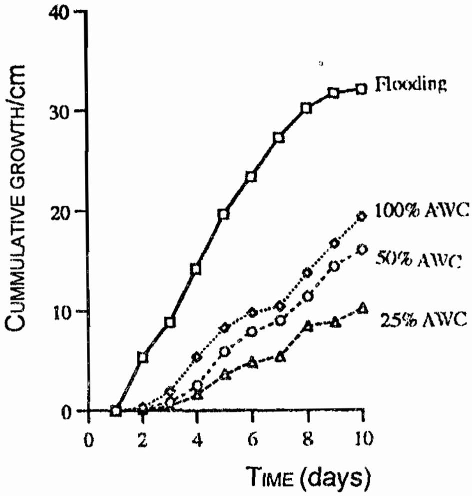

Fig.1. Cummulative growth curve of shallots subjected to water stress.

Results and discussion

Thirteen weeks of water stress did not significantly (P>0.05) affect green leaf number (Table 1). At maturity, the flooded plants had the highest green leaf number. This could be ascribed to continued vegetative growth while the other treatments were dying back because they had either reached physiological maturity (100 per cent AWC) or advanced maturity (25 and 50 per cent AWC) as a result of stress, and were, therefore, not producing new leaves. Pronounced vegetative growth in the flooded shallots was indicated by high cummulative growth rate (Fig. 1). Leaf area increased by about 38 and 50 per cent in the non-stressed shallot over the 50 and 25 per cent AWC treatments, respectively (Table 1). Reduction in leaf area of the stressed shallots was a mechanism to conserve the little water in their tissues. It could also be attributed to long-term effect of stress on plant growth as has been observed in plants by Jones (1994) and Salisbury & Ross (1992).

Water stress adversely affected RWC of shallot plant tissues. Non-stressed and flooded plants had the highest RWC values. The RWC values (Table 1) of the stressed and flooded plants indicated that the imposition of stress led to reduction in leaf area, senescence, and advance maturity to conserve tissue water content. It was also observed that stressed shallots underwent periodic temporary wilting and had waxy cuticle. These observations are consistent with those made by Brewster (1994), Salisbury & Ross (1992), and Rana & Sharma (1994). Slatyer (1967) reported that for continuous active metabolism, plant tissue water content should fluctuate within a narrow limit of 20 to 25 per cent of

TABLE 1

Effect of Water Stress on Green Leaf Number, Leaf Area, Plant Shoot Fresh and Dry Weights, and Relative Water Content of Shallots

Treatment	*Green leaf number 21 WAP*	*Green leaf number Maturity*	*Mean Leaf area (cm²)*	*Plant shoot FW (g)*	*Plant shoot DW (g)*	*RWC (%)*
Flooded	28	22	-	17.4	1.8	89
100 % AWC	24	15	110.8	10.4	1.1	85
50 % AWC	27	13	67.4	5.6	0.6	79
25 % AWC	23	15	54.9	6.1	0.7	72
		*	**	**	**	*
LSD (5 %)	NS	8	18.7	5.1	0.6	16
CV (%)	11	13	15.1	8.3	9.5	9

WAP = weeks after planting; FW = fresh weight; DW = dry weight; AWC = available water content; RWC = relative water content; *Significant at P = 0.05; **Significant at P = 0.01; NS = Non-significant.

the saturated tissue water content value, since most growth processes cease when values fall outside this limit; hence; the permanent wilting and death of shallot plants subjected to continuous dryness.

The effect of water stress on lateral branching was found to be temporal, since it is a direct function of bulb number which was found to be equal in all the treatments at final harvest (Tables 2 and 3). Most of the non-stressed plants produced three to six lateral shoots (branches) compared to two to four lateral shoots produced by most of the stressed plants. Like the bulb number and lateral branching, number of axillary buds was unaffected by water stress (Table 3). These suggest genotypic control of these traits in shallots, although the time rate of lateral branching was influenced by water stress. Enhanced growth characteristics of adequate and regularly watered plants resulted in higher bulb weights and yields (Table 3). Harvest index (Table 3), which is the proportion of the total dry matter harvested as the economic yield, was significantly ($P<0.05$) higher in the non-stressed plants compared to the stressed ones. Thus, adequate watering in shallots resulted in larger sink for higher yields.

The observations made in this study are consistent with those of Levy *et al.* (1981), Brewster (1994), and Rana & Sharma (1994). Water stress had adverse effect on shallot growth, development, maturity, and yield. However, the severity of these depended on stress level. Shallot tissue water content is unaffected by water stress. Number of lateral shoots and bulb number decreased with increased stress. The study also suggested that adequate irrigation, for amount and timeliness, may reduce or eliminate constraints on cell expansion and development. This prolongs the duration of green leaf area to serve as large source of assimilate, which is then mobilized and stored in leaf bases to increase shallot bulb dry matter and yield.

TABLE 2

Effect of Water Stress on Lateral Branch Production in Shallots

Number of lateral branches	*Number of plants*		
	100 % AWC	*50 % AWC*	*25 % AWC*
1	2	0	4
2	3	8	12
3	9	15	12
4	10	11	7
5	6	1	1
6	5	1	0
7	1	0	0

TABLE 3

Effect of Water Stress on Yield Components and Yield of Shallots

Treatment	*Mean number of*		*Mean bulb weight (g)*	*Bulb yield (g/plant)*	*Harvest index*
	axillary buds/plant	*bulbs/ plant*			
Flooded	6	9	2.2	19.8	0.44
100 % AWC	9	7	2.7	20.0	0.69
50 % AWC	6	6	0.9	4.3	0.37
25 % AWC	7	7	0.9	5.1	0.39
			*	*	**
LSD (5%)	NS	NS	1.6	5.5	0.15
CV (%)	9	17	20.4	23.3	5.20

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