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INFLUENCE OF KINETIN ON PHOTOSYNTHESIS, NITROGEN METABOLISM AND YIELD OF CLUSTERBEAN UNDER MOISTURE DEFICIT CONDITION

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SUMMARY

Kinetin (5 ppm) applied as either pre-sowing seed treatment or foliar spray (at 25 and 40 DAS) or both significantly improved the growth, dry matter production and seed yield of field grown clusterbean (*Cyamopsis tetragonoloba)* under moisture deficit condition. Besides favourably affecting net photosynthetic rate and nitrate reductase activity, it also resulted in more partitioning of photosynthates towards seeds, resulting in higher harvest index. Kinetin mediated response was due to higher content of different leaf metabolites (starch, soluble protein, etc.) thereby, prolonging the active growth phase.

Key words : **Clusterbean, kinetin, leaf metabolites, nitrate reductase, photosynthesis.**

INTRODUCTION

Clusterbean (*Cyamopsis tetragonoloba* (L) Taubert), a drought hardy crop, is grown in regions receiving an annual rainfall of 200-600 mm. Growth and yield of the crop is, however, limited due to low precipitation and frequent droughts.

Though alleviation of adverse effects of stress on growth and yield of plants through use of plant growth regulators have earlier been reported (Naqvi 1985) but information on use of kinetin under field stress condition is meagre. Most of the efforts in this direction are either in pot or nutrient culture of leaf discs trials (Gzik *et al.* 1987, Khalil and Mandurahi 1989).

The present investigation was, therefore, undertaken to assess the feasibility of alleviation of adverse effects of water stress under arid conditions of western Rajasthan, and to understand various physiological processes associated with kinetin mediated alleviation of deleterious effects of field drought in clusterbean.

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MATERIALS AND METHODS

Field study was conducted with clusterbean (*Cyamopsis tetragonoloba* (L) Taubert) under rainfed conditions during 1999 at the Central Research Farm of the Institute at Jodhpur. The experimental soil was a typic camborthid with 7.1% clay, 5.6% silt, 63.1% fine sand and 24% coarse sand, having 0.28% organic carbon and 0.023% total nitrogen. The soil contained 80 kg ha^{-1} available N, 12 kg ha^{-1} available P and 120 kg ha^{-1} available K. The soil held 10.0% and 3.0% moisture at field capacity (–0.3 bar) and permanent wilting point (–15.0 bar), respectively, while the infiltration rate was 15 cm ha^{-1}.

Clusterbean (cv. RGC 936) was sown in field plots (4.5 × 3.6 m) on 21st July, 1999 after a precipitation of 25.1 mm was received during preceding three days. Seven treatments were laid in randomized block design with four replications each [T_1 : control, T_2 : seed soaking in water (STW) for 4 h followed by drying on filter paper for 1 h in shade, T_3 : seed soaking in kinetin

(5 ppm; STK) for 4 h followed by drying as in T_2, T_4 : foliar spray of water (FSW) at 25 and 40 DAS, T_5 : foliar spray of kinetin (5 ppm, FSK) at 25 and 40 DAS, T_6 : (T_2 + T_4); and T_7 (T_3 + T_5)].

Soil moisture was determined gravimetrically up to one meter depth every 10 days from sowing to harvest and consumptive use of water was computed adopting water balance equation. Shoot water potential was determined at 40 and 50 days after sowing (DAS), where plants were gently uprooted, cut at the soil surface and water potential was measured using pressure chamber (PMS Instrument Company, USA). Observations on leaf area (using LICOR-3000 area meter) were recorded at the flowering stage (50 DAS) besides analysis of two upper most fully expanded leaves for contents of total chlorophyll (Arnon 1949), starch (Yemm and Willis 1954), soluble protein (Lowry *et al.* 1951), free amino acids (Yemm and Cocking 1955) and nitrate reductase activity (Jaworski 1971). Net photosynthetic rates were measured in the two upper most fully expanded leaves using LICOR-6200 portable photosynthetic system. These measurements were made on four randomly selected plants under each treatment between 10.00-11.00 a.m. with intact plants in the field. Plant performance was adjudged from final plant height, above ground dry matter and seed yield with observations based on four replicates. Water use efficiency (WUE), was computed in terms of seed yield per unit of water utilized. The significance of data was adjudged through analysis of variance, wherever necessary.

RESULTS AND DISCUSSION

In 1999, the total cropping period was of 70 days with the total seasonal precipitation of 178.4 mm occurring during the nine rain events (Fig. 1a). After 4th August, there were very little rains. Consequently, soil moisture was invariably below the availability limit (45 mm) during the critical last four weeks (Fig. 1b) of crop growth.

Plant water potential (Ψ_{plant}) at 50 DAS (flowering stage) was markedly lower than at 40 DAS in all the treatments (Table 1), thereby clearly reflecting progressive development of plant water deficit condition with advancing age and due to soil drying. All kinetin treated plants displayed significantly more leaf area (at 50 DAS) compared to either control or water treated plants (Table 1), which might have resulted in steeper decline in Ψ_{plant}.

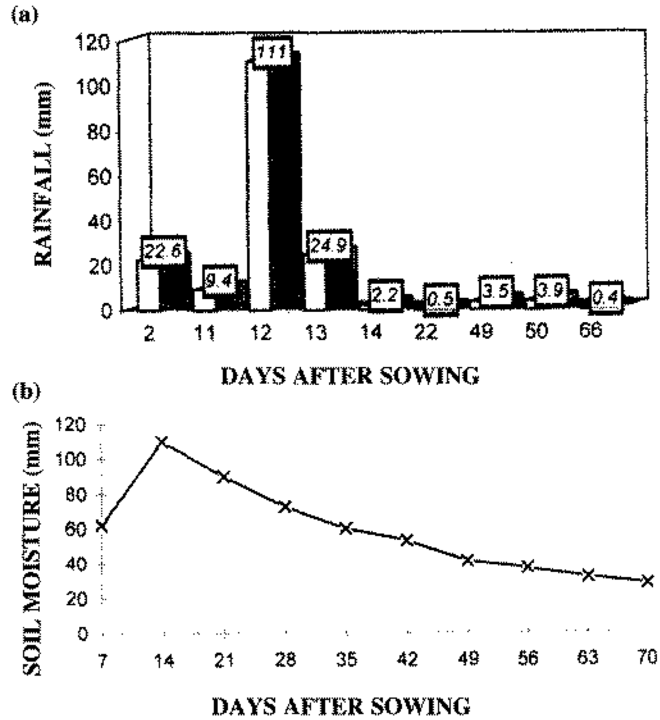

Fig. 1. Rainfall (a) and soil moisture upto 1 m depth (b) in clusterbean plots during the cropping period (Field capacity 150 mm; PWP 45 mm).

Kinetin used as seed treatment or foliar spray individually or in combination increased the seed yield as compared to control plants (Table 2). The beneficial effects cannot be attributed to moisture as simple water application either as seed soaking or foliar spray did not significantly increase the seed yield. Pre-soaking seed treatment with kinetin enhanced seed yield by 26.0% while foliar spray increased it by 43.6% over control plants. However, maximum favourable effects of kinetin were obtained with combined application of seed treatment plus foliar spray which increased seed yield by 68.6% over untreated plants. Kinetin mediated increase in seed yield under water stress has also been reported for wheat (Shang *et al.* 2000). Comparatively more height of kinetin treated plants also indicates the beneficial effect in general on plant growth.

Kinetin application was associated with a high harvest index (Fig. 2), thereby, indicating partitioning of more photosynthates towards seed. Significantly higher seed yield in kinetin treated plants also led to higher water use efficiency (WUE) in spite of lower or comparable water use in control and water treated plants (Fig. 3). The kinetin

Table. 1 Plant water potential and leaf area of clusterbean plants subjected to different treatments

Treatments	Plant water potential (–bars)		Leaf Area at 50 DAS (cm^2 $plant^{-1}$)
	40 DAS	50 DAS	
T_1-(Control)	11	16[a]	233.1[a]
T_2-(ST W)	11	17[a]	255.2[a]
T_3-(ST K)	10	23[a]	342.4[c]
T_4-(FS W)	11	16[a]	248.4[a]
T_5-(FS K)	10	20[b]	306.2[b]
T_6-(W + W)	10	15[a]	263.8[ab]
T_7-(K + K)	12	23[c]	386.9[c]
SEm ±	0.58	0.69	16.7
LSD (0.05)	NS	2.1	49.7

Values with different superscript are statistically significant at 5% level.

Table. 2 Plant height, dry matter and seed yield of clusterbean plants subjected to different treatments

Treatments	Plant height (cm)	Seed yield (kg ha^{-1})	Dry matter (kg ha^{-1})
T_1-(Control)	24.8[a]	204[a]	926[a]
T_2-(ST W)	25.2[a]	227[a]	978[a]
T_3-(ST K)	28.2[b]	257[ab]	1033[ab]
T_4-(FS W)	25.4[a]	231[a]	1028[a]
T_5-(FS K)	27.7[b]	293[bc]	1186[b]
T_6-(W + W)	25.5[ab]	232[a]	1054[a]
T_7-(K + K)	32.3[c]	344[c]	1401[c]
SEm ±	0.91	20.2	51.5
LSD (0.05)	2.7	60	153

Values with different superscript are statistically significant at 5% level.

mediated increase in WUE assumes more importance under situations where interruption of cytokinin supply from roots due to soil drying results in restricted stomatal opening and water use (Blackman and Davies 1985).

Kinetin also favourably affected two important plant processes viz. photosynthesis and nitrogen metabolism. Net photosynthetic rate and nitrate reductase activity significantly increased in plants treated with kinetin (Tables 3 and 4). In both cases the effects of water soaking or spray were not significant, thereby indicating that the beneficial effects of kinetin cannot be attributed simply to moisture. Our results are in concurrence with earlier results of Gzik *et al.* (1987) in sugarbeet and Shang *et al.* (2000) in wheat. Significant increase in content of the total chlorophyll with kinetin application (Table 3) as

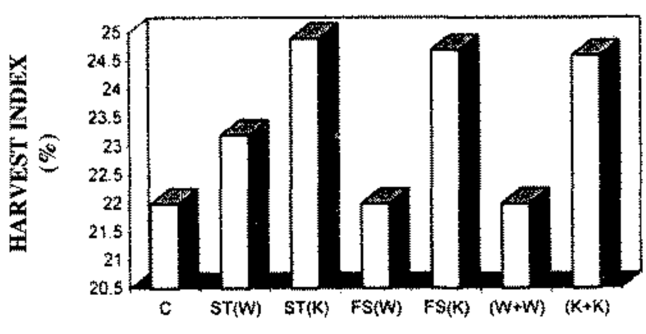

Fig. 2. Harvest index of clusterbean subjected to different treatments

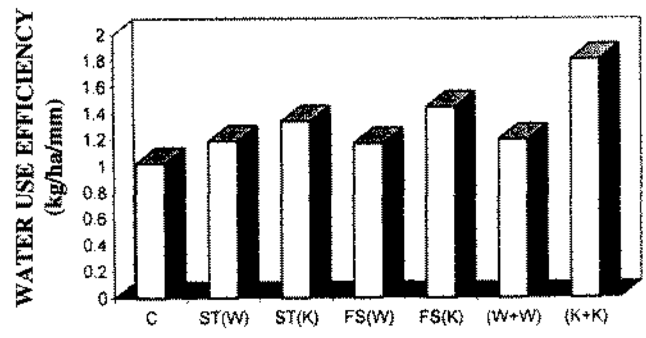

Fig. 3. Water use efficiency (WUE) of clusterbean subjected to different treatments

also reported by Khalil and Mandurahi (1989) may also be responsible for the observed increase in photosynthesis (Gzik *et al.* 1987).

The concentrations of starch, soluble protein and free amino acids were maximum when kinetin was applied both as seed treatment and foliar spray (Tables 3 and 4). This could be due to kinetin mediated increase in photosynthetic and nitrate assimilation activity besides decrease in protease activity and immobilization of nutrients and metabolites from kinetin treated tissues as reported by Kumari and Bharti (1992). Seed treatment with either water or kinetin invariably caused less increase of these metabolites.

The study had shown that under moisture deficit conditions, as most often encountered in arid and semi-arid regions, application of kinetin either as foliar spray or seed treatment plus foliar spray could significantly improve the growth and seed yield of clusterbean. The beneficial effects of kinetin were attributed due to its role in increased photosynthetic rates, better carbohydrate metabolism and enhanced nitrate reductase activity.

Table 3. Net photosynthetic rate, total chlorophyll and starch content of leaves of clusterbean plants subjected to different treatments.

Treatments	Net photosynthetic rate ($\mu mol\ m^{-2} s^{-1}$)	Total chlorophyll ($mg\ g^{-1}$ dw)	Starch ($mg\ g^{-1}$ dw)
T_1-Control	10.30^a	3.29^a	149.0^a
T_2-ST (W)	11.34^a	4.07^a	155.5^a
T_3-ST (K)	13.27^b	4.75^b	235.5^b
T_4-FS (W)	10.56^a	4.09^a	230.5^a
T_5-FS (K)	14.04^{bc}	4.96^b	232.5^b
T_6-W + W	11.50^a	4.17^b	232.5^b
T_7-K + K	14.82^c	5.44^c	265.5^c
SEm	0.41	0.12	5.9
LSD (0.05)	1.22	0.36	17.5

Values with different superscript are statistically significant at 5% level.

Table 4. Nitrate reducase activity, soluble protein and free amino acid content of leaves of clusterbean subjected to different treatments.

Treatments	Nitrate reductase activity ($\mu g\ NO_2^-\ g^{-1}$ dw h^{-1})	Soluble protein ($mg\ g^{-1}$ dw)	Free amino acids ($mg\ g^{-1}$ dw)
T_1-Control	434.4^{a}	136.3^{a}	4.63^{a}
T_2-ST (W)	440.5^{a}	133.1^{a}	5.79^{a}
T_3-ST (K)	486.4^{b}	148.2^{b}	6.57^{c}
T_4-FS (W)	436.6^{a}	143.8^{ab}	6.01^{b}
T_5-FS (K)	548.4^{c}	158.8^{b}	6.77^{c}
T_6-W + W	451.9^{ab}	130.7^{a}	6.22^{b}
T_7-K + K	530.0^{c}	158.2	7.35^{d}
SEm ±	13.5	3.5	0.18
LSD (0.05)	40.0	10.5	0.55

Values with different superscript are statistically significant at 5% level.

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