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Research article

INTERACTION OF ELEVATED CO_2 AND MOISTURE STRESS ON BLACKGRAM GROWTH AND YIELD

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ABSTRACT: An experiment was conducted with blackgram (*Vigna mungo* L. Hepper) cv T-9 in Open top chambers (OTCs) to assess the impact of moisture deficit and its interaction with two levels of CO_2 (550ppm and 700ppm) on biomass and seed yield. At flowering stage moisture deficit was imposed by withholding irrigation. Both elevated CO_2 levels improved the total biomass and the extent of improvement was 2.7% and 23.5% under irrigated conditions, while 9.0% and 26.1% under moisture stress conditions at 550ppm and 700ppm of CO_2 respectively. Higher improvement in seed yield than biomass at both elevated CO_2 levels was recorded and under irrigated condition the seed yield improved by 26.3% and 58.9% while under moisture deficit conditions by 9.0% and 34.7% at 550ppm and 700ppm respectively. Though moisture deficit reduced the total biomass, seed yield and HI at all CO_2 levels, however the magnitude of reduction was less at elevated CO_2 levels. The ameliorative effect of enhanced CO_2 concentrations under moisture deficit condition was observed through better pod number in blackgram as compared with ambient control which reflected as higher seed yield.

Key words: Moisture deficit, Elevated CO_2, Total biomass, pod number, HI

INTRODUCTION

The experiments with different confined as well as OTCs and FACE facilities revealed that legumes have an advantage under elevated CO_2 over non-leguminous plants (Roger *et al*., 2006). A sustained and maximal stimulation in productivity at elevated CO_2 requires an enhanced nutrient supply to match the increase in C acquisition. The ability of legumes to exchange carbon for nitrogen with their N-fixing symbionts has led to the hypothesis that legumes will have a competitive advantage over non-leguminous species when grown at elevated CO_2. C_3 plants are more responsive to elevated CO_2 than cereals and oilseed crops (Ainsworth and Long 2005, Vanaja *et al*., 2006, Reddy *et al*., 2010). Growth at elevated CO_2 stimulates photosynthesis and increases carbon supply in C_3 species. Yield of most agricultural crops will increase under elevated CO_2 with productivity increase in the range 15% to 41% for C_3 crops and 5% to 10% for C_4 crops (Cure 1985; Kimball 1983; IPCC 2007). Black gram (*Vigna mungo* (L.) Hepper) as a legume crop has the ability to fix atmospheric nitrogen and is one of the highly prized pulses of India. It has originated in India and it has been in cultivation from ancient times. With predicted future global scenario of CO_2 increase, changes in temperature and water availability it expected to affect many key metabolic processes and growth in plants. In the present study an attempt was made to understand the interactive effect of the elevated CO_2 and moisture deficit on growth and yield response of blackgram and to quantify its ameliorative capacity at two levels of elevated CO_2.

MATERIALS AND METHODS

Black gram cv. T-9 plants were raised in open top chambers (OTCs) having 3m × 3m × 3m dimensions lined with transparent PVC (polyvinyl chloride) sheet having 90% transmittance of light. The plants were evaluated for moisture deficit impact and its interaction with elevated CO_2 concentrations (550 and 700ppm) in terms of growth, biomass and yield parameters. There were three CO_2 levels (ambient, 550ppm, 700ppm) and two irrigation levels (well watered and moisture deficit at flowering stage). The elevated CO_2 concentrations of 550ppm and 700ppm were maintained within OTCs throughout the study by injecting pure CO_2 and the OTCs without any CO_2 supply served as ambient (390ppm) control (Vanaja *et al*., 2006). The desired CO_2 concentrations within the OTCs were maintained and monitored continuously throughout the experimental period by means of CO_2 analyzer.

Blackgram plants were raised in 5 liter capacity pots filled with approximately 6.5 kg of red soil and twelve pots with one plant per pot were maintained at each CO_2 concentration within OTCs. At flowering stage, half of them at three CO_2 concentrations were subjected to moisture deficit by withholding the irrigation (Vanaja *et al*., 2011) while the rest of the pots maintained stress free by providing irrigation. The soil water content of stress imposed pots was determined by weighing the pots daily and maintained at 50% field capacity (FC). Once wilting symptoms appeared, the stress was released by irrigating the pots and maintained stress free till harvest.
At harvest the observations were recorded on six plants each for irrigated and moisture deficit treatments of individual CO_2 concentration on plant height, number of branches, root length, number of pods, pod weight, seed yield, seed number, test weight. After drying of plants to constant weight, dry biomass of root, stem, and leaf were recorded and total biomass and HI were computed. The root volume was quantified by water displacement method and expressed as ml. The data was analyzed statistically by using ANOVA to test the significance of CO_2 levels, irrigation levels and their interaction.

RESULTS AND DISCUSSION

The ANOVA revealed that irrigation levels were highly significant ($P \leq 0.01$) for leaf biomass, root biomass, root volume, pod weight, total biomass, seed number, seed weight, test weight and HI (Table 1). The CO_2 levels were significant for majority of the traits except plant height, root length, number of branches and shoot biomass. The interaction of irrigation levels and CO_2 levels were significant for root biomass, root volume, pod weight, seed number, seed yield and test weight.

Plant height

In general, increased plant height was recorded at both elevated CO_2 levels as compared with ambient control while moisture deficit reduced it at all CO_2 levels with less reduction at elevated CO_2 condition. Under irrigated condition, the plant height was 29cm at ambient, 29.6cm at 550ppm and 30.5 cm at 700ppm, while it reduced to 27.8, 28.8 and 29.0cm at ambient, 550ppm and 700ppm respectively under moisture stress condition (Fig. 1). The increase in plant height was to the extent of 1.4% and 3.6% with 550ppm, 4.57% and 4.8% with 700ppm over ambient control under irrigated and moisture stress conditions respectively, revealing a higher response under moisture stress environment. Similar results with black gram also showed an increase plant height at elevated CO_2 levels under irrigated conditions Vanaja *et al.* (2007).

Root length

Enhanced CO_2 levels increased root length as compared with ambient control and moisture stress induced higher root length at all CO_2 levels as compared with respective irrigated controls. The root length was 34.6cm at ambient and 41.6cm at 550ppm and 42.8cm at 700ppm under irrigated condition, whereas under moisture stress condition they were 41.0cm, 43.5cm and 44cm at ambient, 550ppm, and 700ppm respectively (Fig. 1). The improvement in root length under moisture deficit condition was to the extent 20.2% and 6.1% at 550ppm, 23.6% and 7.3% at 700ppm over ambient control under irrigated and moisture stress conditions respectively, revealing better response under moisture stress environment and higher response with elevated CO_2 condition. Madhu *et al.* (2013) also reported that increased root length with increased CO_2 conditions in ground nut crop.

Root volume

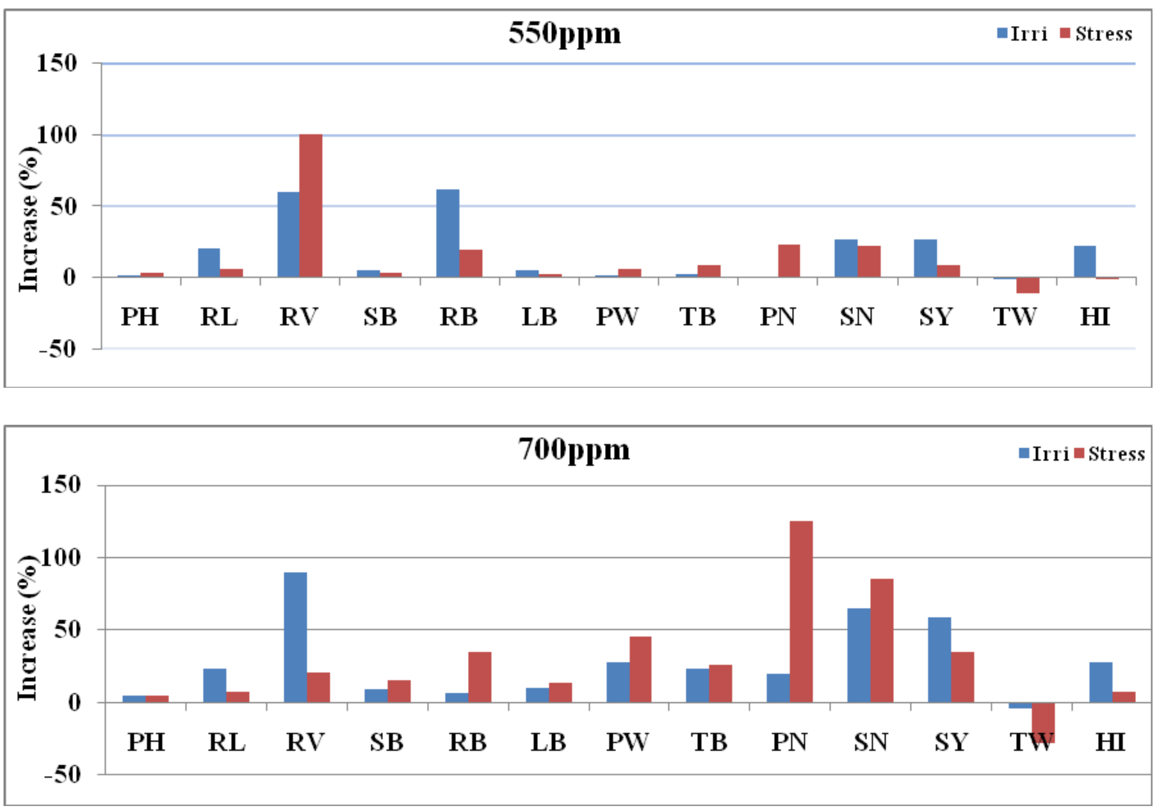
The root volume increased at both elevated CO_2 levels as compared with ambient control. With moisture deficit the increased root volume was recorded at ambient and 550ppm while it reduced at 700ppm CO_2 as compared with respective irrigated controls. The increase in root volume was linear with increased CO_2 concentration under irrigated condition with 3.3ml at ambient and 5.3ml at 550ppm and 6.3ml at 700ppm. While, under moisture deficit condition, the values are 4.0ml, 8.0ml and 4.8ml at ambient, 550ppm, and 700ppm respectively. The increase in root volume under stress condition was to the extent of 60% and 100% at 550ppm; 90% and 20.83% at 700ppm under irrigated and moisture stress conditions respectively over ambient control (Fig.1). The advantage of elevated CO_2 in improvement of root volume was there up to 700ppm under irrigated condition whereas with moisture deficit, the advantage was observed at 550ppm only. In ground nut crop, Madhu *et al.* (2013) reported that increase in root biomass and volume at increased CO_2 conditions.

Stem biomass

Stem biomass was increased at both elevated levels of and under both irrigated and moisture deficit conditions as compared with ambient CO_2 and the increase was 4.9% at 550ppm and 9.4% at 700ppm under irrigated conditions, 3.3% and 15.3% under moisture deficit condition at 550ppm and 700ppm respectively (Fig. 1).

Table 1. Morphological, biomass and yield parameters of black gram (T-9) under irrigated and moisture deficit (Treatments) conditions at three levels of CO_2 (ambient, 550ppm, 700ppm) and significance levels.

Plant parameters	CO_2 levels						Irrigation levels	CO_2 levels	Irrigation levels x CO_2 levels
	Ambient		550ppm		700ppm				
	Irrigated	Stress	Irrigated	Stress	Irrigated	Stress			
Plant height (cm)	29.2	27.8	29.6	28.8	30.5	29.1	*	NS	NS
Root length (cm)	34.5	41.0	41.6	43.5	42.7	44	NS	NS	NS
No. of Branches	4.1	4.3	4.3	4.6	5	5	NS	NS	NS
Root volume (ml/pl)	3.3	4.0	5.3	8.0	6.3	4.8	*	**	**
Stem biomass (g/pl)	3.3	3.2	3.4	3.4	3.7	3.5	NS	NS	NS
Root biomass (g/pl)	0.67	0.75	0.80	1.20	0.91	0.80	**	**	**
Leaf biomass (g/pl)	3.4	2.9	3.5	3.1	3.9	3.2	**	**	NS
Pod weight (g/pl)	11.8	5.8	12.0	6.2	15.2	8.5	**	**	NS
Total biomass (g/pl)	19.2	12.8	19.8	13.9	23.7	16.1	**	**	NS
Pod number/pl	42.8	13.3	43.0	16.4	51.3	30.0	**	**	**
Seed number/pl	150	58	191	71	248	107	**	**	**
Seed yield (g/pl)	6.2	3.9	7.8	4.2	9.9	5.2	**	**	**
Test weight (g)	4.1	6.8	4.1	6.0	4.0	4.9	**	**	**
HI (%)	32.5	30.5	39.9	30.5	41.5	32.8	**	*	NS



PH- Plant height; RL-Root length; RV-Root volume; SB-Stem biomass; RB-Root biomass; LB-Leaf biomass; PW-Pod weight; TB-Total biomass; PN-Pod number; SN-Seed number; SY-Seed yield; TW-Test weight; HI-Harvest index

Fig. 1: Increase (%) of morphological, biomass and yield parameters of black gram (T-9) under irrigated and moisture deficit conditions at 550ppm, 700ppm CO_2 over ambient control.

Root biomass

The root biomass increased at both levels of elevated CO_2 compared with ambient control. The increase in root biomass under moisture stress condition was to the extent 6.9% and 34.7% at 550ppm; 61.5% and 19.2% at 700ppm over ambient control under irrigated and moisture deficit conditions respectively revealing better response under stress environment (Fig.1). Similar results were also reported in black gram (Vanaja *et al.,* 2007), wheat (Chaudhuri *et al*., 1990), soybean (Del Castillo *et al*., 1989), and Groundnut (Pilumwong *et al*., 2007) at elevated CO_2 levels.

Leaf biomass

Leaf biomass was increased in both elevated CO_2 levels compared with ambient control. The biomass was increased 5.6% at 550ppm and 13.9% at 700ppm in irrigated plants over ambient control. Similarly increased leaf biomass 3.6% at 550ppm and 10.3% at 700ppm recorded at stress conditions (Fig.1). In black gram, Vanaja *et al.* (2007), Ratnakumar *et al.* (2010) reported that increased leaf biomass at elevated CO_2 levels under irrigated conditions.

Pod weight

Pod weight was more increment in 700ppm CO_2 level compared with ambient control under irrigated conditions that was 27%, and in 550ppm increase is there but the increase was less that is 1.3% .In moisture stress conditions at 550ppm 6% and in 700ppm 45.9% increase in pod weight under stress conditions compared with ambient control (Fig.1). Similarly in black gram, Vanaja *et al*. (2015) and Jyothi Lakshmi *et al.* (2013) reported that increased pod weight at elevated CO_2 under irrigated condition.

Total biomass

The total biomass was increased in both levels of elevated CO_2 in irrigated and moisture deficit conditions also. The total biomass at ambient control was 19.2g/pl under irrigated and 12.7g/pl in moisture stress condition. At 550ppm the total biomass was 19.7g/pl under irrigated condition and 13.9g/pl in moisture deficit condition while in 700ppm level the total biomass was recorded 23.7g/pl under irrigated condition and 16.1g/pl under moisture stress condition (Fig.1). The total biomass recorded an improvement of 2.7% at 550ppm and 23.5% at 700ppm under irrigated and in moisture tress conditions 9% at 550ppm and 26.1% at 700ppm over ambient control (390ppm). Vanaja *et al.* (2007, 2015) also reported that increased total biomass in black gram at elevated CO_2 levels under irrigated conditions.

Pod number

The pod number increased at both elevated CO_2 levels as compared with ambient control. Moisture stress reduced the pod number at all CO_2 levels, however the magnitude of reduction was less at elevated CO_2 condition. The pod number at ambient was 42/pl and it improved to 43/pl at 550ppm and 51/pl at 700ppm under irrigated condition. Whereas under moisture stress conditions the values are 13, 16, and 30 at ambient, 550ppm and 700ppm respectively (Fig.1). Jyothi Lakshmi *et al.* (2013) also reported that increased pod number at elevated CO_2 under irrigated condition in black gram.

Seed number

Elevated CO_2 levels increased the seed number than ambient control under both irrigated and moisture deficit conditions. The seed number was 150/pl at ambient control, 190/pl at 550ppm and 248/pl at 700ppm under irrigated condition. With moisture deficit the number of seed were 57/pl, 71/pl and 107/pl at ambient, 550ppm and 700ppm respectively (Fig.1). Though seed number decreased with moisture deficit condition, higher seed number was recorded at both elevated CO_2 improved the under both irrigated as well as moisture deficit conditions. Similar results were reported in black gram (Vanaja *et al*., 2007) and rice (Uprety *et al*., 2000) at increased CO_2 concentrations under irrigated conditions.

Seed Yield

The seed weight increased at both elevated CO_2 levels as compared with ambient control. Moisture deficit reduced the seed weight at all CO_2 levels and decrease was less with elevated CO_2 levels than ambient control. The average seed weight was 6.2g/pl at ambient 7.8g/pl at 550ppm and 9.9g/pl at 700ppm under irrigated condition. Whereas under moisture deficit condition the values are 3.9g/pl, 4.2g/pl and 5.2g/pl at ambient, 550ppm and 700ppm respectively. The increase in seed weight was to the extent of 26.3% and 9.0% at 550ppm; 58.9% and 34.7% at 700ppm over ambient control under irrigated and moisture deficit conditions respectively. The higher pod number resulted higher seed yield at 700ppm even under moisture deficit condition. Similar response of improved seed yield in redgram at elevated CO_2 levels under irrigated conditions were reported (Vanaja *et al*. 2010). Similarly in soybean, Hao *et al*. (2012) revealed that increased seed yield with increasing of the pod number from FACE experiments.

Harvest index

The harvest was increased in both elevated CO_2 in irrigated and moisture stress conditions as compared with ambient control. The increase was more at 700ppm than 550ppm under both irrigated and moisture deficit treatments. The harvest index improved by 22.5% and 0.2% at 550ppm under irrigated and moisture deficit conditions respectively whereas at 700ppm the improvement was 27.6% under irrigated and 7.7% under moisture deficit conditions. The increased harvest index at two elevated CO_2 levels under irrigated conditions in black gram was reported by Vanaja *et al.* (2007). It is clearly indicating that enhanced CO_2 not only improving biomass but also influencing its partitioning to economic parts.

CONCLUSION

From the above results it is clearly evident that moisture deficit reduced the biomass and seed yield of black gram (T-9) and both elevated CO_2 (550ppm & 700ppm) concentrations improved these parameters. Higher ameliorative effect of 700ppm was observed especially in realizing better seed yield under moisture deficit condition due to maintaining higher pod number.

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