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Yield and harvest index of short and long duration grain legume crops under twice the ambient CO_2 levels*

M VANAJA[1], P RAGHU RAM REDDY[2], N JYOTHI LAKSHMI[3], S K YADAV[4], A NARASIMHA REDDY[5], M MAHESWARI[6] and B VENKATESWARLU[7]

Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad 500 059

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Foodgrain requirements of India (both human and cattle) are estimated at 300 million tonnes in 2020 (Sinha *et al*. 1998). With the alarming increase in GHG concentration and its expected impact on climate, the issue emerging would be to achieve the targeted production. To address the above issue from the agricultural point of view, it is desirable to select the crops and their cultivars thereof, that can better utilize the increased concentration of CO_2 for both biomass and grain yield.

In case of food legumes where grain is harvested for human consumption, the translation of increased biomass more towards grain or improved harvest index need to be achieved for breaking the yield barriers of these very important C3 grain legumes predominantly grown in the marginalized rainfed areas. India is the largest producer and consumer of pulses in the world. India grows pulses in about 22.5 million ha and 80% is in dry areas. However, pulses production has been stagnant at between 11 and 14 million tonnes over the last two decades. Per capita pulses consumption over the years has come down from 61 g/day in 1951 to 30 g/day in 2008 (Amarender Reddy 2009). Elevated CO_2 condition appears to improve the overall growth of plants in general and may result in changes in partitioning of photo assimilates to various plant organs over time. An attempt was made to quantify the response of two major rainfed grain legume crops, viz pigeonpea and blackgram to increased atmospheric CO_2 level in terms of total biomass, grain yield, fodder yield and partitioning efficiency.

The seeds blackgram cv. T 9 with crop duration of 75–80 days and pigeonpea cv. ICPL 88039 with crop duration of 110–120 days were sown in open top chambers (OTCs) of 3 m × 3 m diameter lined with transparent PVC (polyvinyl chloride) sheet, which had 90% transmittance of light. The extra short-duration pigeonpea (cv. ICPL 88039) seeds were obtained from ICRISAT, Patancheru, Hyderabad and blackgram (cv. T 9) seeds were procured from Lam Farm Research Station of APAU, Guntur, Andhra Pradesh. The study was conducted during rainy (*kharif*) season of 2009 at Central Research Institute for Dryland Agriculture, Hyderabad, India. The seeds were sown directly in the soil (Alfisol) within the OTC's and following recommended agronomy practices. The elevated level of CO_2 was maintained throughout 24 hr a day from sowing to final harvesting and two OTCs without any external CO_2 supply served as ambient control. To maintain the elevated level of CO_2 concentration in two OTCs, i e 700ppm at crop canopy level, continuous injection of 100% CO_2 into plenum of OTCs was done where it was mixed with air from air compressor before entering into the chamber. The air sample from each chamber was drawn from the centre point of OTCs at three minutes interval into non-dispersive infrared (NDIR) CO_2 analyzer (California Analytical) and the set level of CO_2 concentration was maintained with the help of solenoid valves, rotameters, Program Logic Control (PLC) and Supervisory Control and Data Acquisition (SCADA) software (Vanaja *et al.* 2006).

The experimental site was sandy loam in texture, neutral in *p*H (6.8), low in available nitrogen (225 kg/ha), phosphorus (10 kg/ha) and medium to high in available potassium (300 kg/ha) and recommended dose of fertilizers were applied to raise the crops. The blackgram crop was harvested at 75 days and pigeonpea crop at 120 days. The chamber conditions during the crop growth period was given in Table 1. Three

*Short note

[1]Principal Scientist (Plant Physiology) (e mail: mvanaja @crida.ernet.in). [2]Principal Scientist (Plant Breeding) (e mail: prreddy@crida.ernet.in). [3]Senior Scientist (Plant Physiology) (e mail: njyothi@crida.ernet.in). [4]Principal Scientist (Biochemistry) (e mail: skyadav@crida.ernet.in). [6]Head, Division of Crop Science (e mail: mmaheswari@crida.ernet.in). [7]Director (CRIDA) (director@crida.ernet.in)

[5]Research Assistant (Plant pathology) (e mail:anreddy @gmail.com). Department of Botany, Osmania University, Hyderabad, Andhra Pradesh 500 007

Table 1 Minimum, maximum and mean values for temperature and relative humidity within OTCs maintained at elevated CO_2 and ambient control during the crop duration of pigeonpea and blackgram in 2009

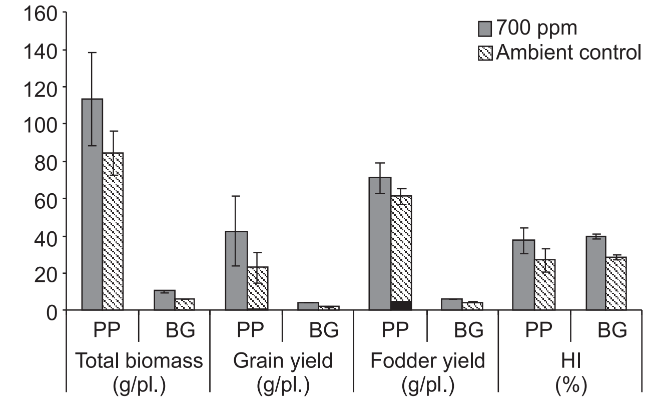
Crop	Pigeonpea		Blackgram	
parameter	Elevated CO_2	Ambient CO_2	Elevated CO_2	Ambient CO_2
Temperature (°C)				
Minimum	16.6	16.5	21.9	19.8
Maximum	40.2	38.0	40.2	38.0
Average	28.3	25.8	27.1	26.6
Relative humidity (%)				
Minimum	16.6	29.6	23.6	32.6
Maximum	87.8	87.7	87.8	87.7
Average	61.1	66.3	61.3	65.7

replications with 15 plants for each replication in each CO_2 levels were harvested and used for recording biomass, grain yield and fodder yield and expressed as g/pl. The Harvest Index was calculated as per the standard procedure as per cent.

The four characteristics in both the crops namely total biomass, grain yield, fodder yield and harvest index were compared at two levels of CO_2 and are presented in Fig 1. The per cent increase for each of these four characters for the two crops under elevated CO_2 over ambient control is presented in Fig 2. The details of character-wise responses were given below.

In pigeonpea, the total biomass improved from 84.1 g/pl at ambient to 113.4 g/pl under elevated CO_2 (Fig 1), there by showing an improvement of 34.8% (Fig 2). In case of blackgram, the value of 6.11 g/pl at ambient improved to 10.11 g/pl under elevated CO_2 showing an increment of 65.5%. In mungbean, Das *et al.* (2002) reported that the biomass response to elevated CO_2 condition at initial growth stages was more (55%) as compared with later growth stages (8%). At elevated CO_2 condition, the increased photosynthesis in all C3 plants result in increased plant biomass and the response of nitrogen-fixing legumes is more as compared with other non-leguminous C3 crops (Rogers *et al*. 2009). This could be due to the unaffected leaf N levels of majority of legumes under elevated CO_2 condition (Winkler and Herbst 2004).

The grain yield of pigeonpea improved from 22.8 g/pl at ambient to 42.4 g/pl at 700ppm (Fig 1), thereby showing an increment of 85.9% with enhanced CO_2 (Fig 2). In blackgram, the grain yield recorded 1.74 g/pl at ambient and improved to 3.99 g/pl at elevated CO_2, thereby revealing an increment of 129.3%. At twice-ambient levels of atmospheric CO_2, Palta and Ludwig (2000) recorded 52 and 55% increases in dry matter and seed yield, respectively in narrow-leafed lupin. In mungbean a significant increases in pod number, pod weight and total seed weight was reported at elevated CO_2 level (Ziska *et al.* 2007).



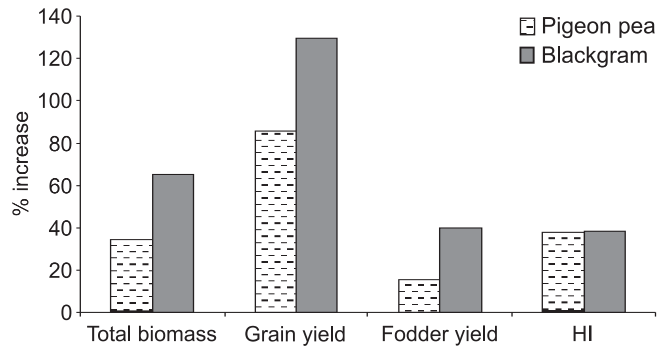


Fig 1–2 **1.** *Per se* values of total biomass, grain yield, fodder yield and HI for pigeonpea (PP) and blackgram (BG) under elevated and ambient CO_2; **2.** % increase of total biomass, grain yield, fodder yield and HI for pigeonpea and black gram under elevated CO_2 over ambient control

The fodder yield of pigeonpea improved from 61.3 g/pl. at 380ppm to 71.0 g/pl at 700ppm (Fig 1), showing an increment of 15.9% with enhanced CO_2 (Fig 2). In blackgram, the improvement was 6.12 g/pl at 700ppm from 4.37 g/pl at ambient level, revealing an increment of 40% with increased CO_2. Legumes are so responsive to atmospheric CO_2 enrichment that they actually increase in abundance within mixed communities. Campbell *et al*. (2000) determined that the legume content of grass-legume swards increased by about 10% in response to a doubling of the air's CO_2 content, which would ultimately make more nitrogen available to the ecosystem's non-leguminous plants.

Both crops maintained a significant positive increase for HI at elevated CO_2, i e from 27.1 and 28.5% HI at 380ppm to 37.9 and 38.8% HI at 700ppm in pigeonpea and blackgram, respectively (Fig 1), thus showing an increment of 37.9 and 38.6% in pigeonpea and blackgram, respectively over ambient values. (Fig 2).This was the resultant of a better pod set and increased seed weight than the increment in total biomass of both the crops under elevated CO_2. Therefore, these crops may be worth-emphasizing for food sustenance with nutritional security under climate change scenario. Above results which are in tune with previously reported results by

Vanaja *et al*. (2007) revealed a significant increase in their HI due to their improved partitioning efficiency under enhanced CO_2 levels. Enriched CO_2 reduced to zero the number of pods that had small seeds (≥30–80 mg) and reduced the number of pods with unfilled seeds from 16 to 1 pod/plant in narrow-leafed source-limited lupin (Palta and Ludwig 2000). This increased seed yield/plant by 44–66%, but did not affect the harvest index.

SUMMARY

The results showed that both the crops recorded significant positive enhanced response for total biomass, grain yield, fodder yield and HI at elevated CO_2. Blackgram recorded higher percentage increase over chamber control than pigeonpea for total biomass, grain yield and fodder yield, but both crops recorded similar values for HI as per cent increase over ambient control. This was the result of a proportionate equal increment in grain yield of both the legume crops under elevated CO_2. Significant increase in HI of both grain legume crops due to their improved partitioning efficiency under enhanced CO_2 levels thus accentuate these crops for sustained food with nutritional security under climate change scenario.

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