ISSN : 1812-5379 (Print)
ISSN : 1812-5417 (Online)
http://ansijournals.com/ja

JOURNAL OF AGRONOMY

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Journal of Agronomy 8 (4): 117-123, 2009
ISSN 1812-5379

Moisture and Planting Density Interactions Affect Productivity in Cowpea (*Vigna unguiculata)*

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Abstract: The aim of this study was to examine the effects of planting density and inter-row spacing on cowpea (*Vigna unguiculata* L. Walp.) productivity at two contrasting moisture regimes. A field experiment was conducted under controlled moisture conditions during the 2007 off-season, at Hawassa University, College of Agriculture, Southern Ethiopia. Treatments were made from a factorial combination of four densities (71428, 95238, 133333 and 200000 plants ha^{-1}), two inter-row spacings (50 and 70 cm) and two levels of water regimes (well watered and dry). The experiment was laid out in a split- split plot design and had three replications with watering regime, inter-row spacing and planting density as main plot, sub-plot and sub-sub-plot factors, respectively. Grain yield and all yield attributes, total biomass and harvest index were decreased by water limitation while none of those traits were significantly affected by inter-row spacing. Moisture x planting density interaction was significant for grain yield ha^{-1}, number of pods m^{-2} and total biomass ha^{-1}. The interaction indicated that an increase in both grain and total biomass yield ha^{-1} was observed with increasing planting density under the wet regime. Grain yield plateau was reached at a density of 160000 plants ha^{-1} under the wet regime. On the other hand, an increase in planting density decreased grain yield and total biomass ha^{-1} under the water-limited condition with the highest yield at the lowest density of 71428 plants ha^{-1}. Thus, farmers could get more out of cowpea by matching their planting density with available moisture. The two inter-row spacings can be used interchangeably by choosing whichever is convenient for management.

Key words: Cowpea, spacing, planting density, moisture regime, yield, yield components

INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp) is one of the important food legumes in the hot-dry tropics and sub-tropics and especially in Sub-Saharan Africa (Singh, 2007). Cowpea plays a substantial role by serving as a grain and vegetable crop mainly for the rural people in the East, West, South and central parts of Africa (Mortimore *et al.*, 1997). According to FAO (2007), cowpea is produced annually on 11.2 mil ha ranking 3rd after common bean (*Phaseolus vulgaris* L.) and chick peas (*Cicer arietinum* L.) with Africa taking the lead followed by Asia.

Yield potential of cowpea is high, averaging 1.5 to 6 t ha^{-1} depending on genotype (Asiwe *et al.*, 2008), though actual yields are the world's lowest among pulses averaging 0.3 t ha^{-1}. As a result, its annual total production is small ranking 8th among ten pulse crops (FAO, 2007) despite its wide area coverage. Yield levels of cowpea vary depending on the quality of the agronomic practices employed. Among these, planting density and row spacing are powerful management tools whereby a grower can strongly influence early season light interception and crop growth (Ball *et al.*, 2000a). Moreover, such agronomic management practices should be designed in accordance with the potential resources of the growth environment like moisture supply. Cowpea is a crop that can be produced under both high and low moisture environments though it is the crop of choice in drier environments due to its high adaptability. When grown under variable environments, the optimum plant density may differ with rainfall and the possibility of water stress. Ball *et al.* (2000a) suggested that plant population may be a strategy for optimizing yield in areas where intermittent drought is common. Thus, it will be important to examine the response of the crop to planting density and inter-row spacing at different moisture regimes.

Most earlier studies on planting density and spatial arrangement deal with cowpea as a component crop in an intercrop combination. However, sole cowpea production

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may play an increasingly greater role due to its ability to grow in stressful environments. It will be useful to sustain food production in the tropics and subtropics where amount and distribution of rainfall is more likely to be unfavorable due to climate change. Singh *et al.* (1997) indicated that cowpea has a great potential for increasing food legume production if grown as a sole crop.

So far, from prior studies made to examine planting density effects of sole cowpea at different moisture levels, no density×moisture interaction is reported. Ismail and Hall (2000) tested semi-dwarf and standard height cowpea at 140000, 188000 and 280000 seed ha^{-1} for the 102, 76 and 51 row spacings, respectively at different environments. They observed that only the semi dwarf lines responded to density by producing the highest yield at the high density because of plant habit×density interaction. However, there was no density×environment interaction most probably due to their use of supplemental irrigation.

Craufurd and Wheeler (1999) compared a range of cowpea densities between 2 and 10 plants m^{-2} under well watered and drought conditions on a short duration cowpea. They observed grain yield reduction by half under drought but did not find interaction between moisture and planting density. Herbert and Baggerman (1983) also tested response of cowpea to row width, density and irrigation at five density levels between 40000 and 340000 plants ha^{-1}. They observed a remarkable response of cowpea to irrigation while that of density response was relatively smaller with no density×moisture interaction. In a crop like cowpea where it can be grown under both high and low moisture environments, identifying such interactions will be useful to ensure optimum productivity. Thus, the aim of the experiment was to examine the response of an erect determinate cowpea cultivar to planting density and inter-row spacing under two contrasting moisture levels.

MATERIALS AND METHODS

The experiment was conducted, at the Hawassa University, College of Agriculture experiment site during the 2007 off-season. Hawassa is situated in Southern Ethiopia at 7°04' N latitude and 38°30' E longitude and at an altitude of 1680 m.a.s.l. Weather records during the crop growth period were obtained from a nearby research station located about 2 km away from the experimental site.

The soil has a pH of 7.5 and contained 48% sand, 26% clay and 26% silt with a textural class of sandy clay loam. Organic matter content of the soil was 2.72%, which is in the medium range. The water content of the soil at field capacity (0.03 MPa) by volume was 27% and at permanent wilting point (1.5 MPa) it was 15% (Fig. 1).

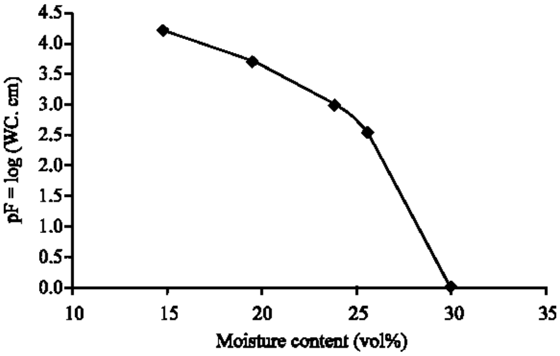

Fig. 1: Soil moisture retention curve of the soil at the experiment site

The cowpea cultivar TVU 1977-OD1 was used in the experiment. The variety has determinate growth habit with erect plant type and has about 100 days of growth duration. Erect cowpea types are more responsive to plant density than the other cowpea types. Planting was made on 19 January 2007. The recommended basal dose of N and P at the rate of 18 and 20 kg ha^{-1} were applied equally to all treatments in the form of urea and triple super phosphate, respectively, at planting. After 15 days of emergence, seedlings were thinned out, leaving one plant per hill to realize the target densities. All other cultural practices such as weeding and cultivation were kept normal and uniform to all treatments.

The treatments were made from a factorial combination of three factors. These include four planting densities (71428, 95238, 133333 and 200000 plants ha^{-1}), two inter-row spacings (50 and 70 cm) and two water regimes (well watered and dry). The experiment was arranged in a split-split plot design with three replications, where water regimes, inter-row spacing and planting density were arranged as main plot, sub-plot and sub-sub-plot factors, respectively. Plant density was obtained by varying the intra-row spacing with the two inter-row spacings as treatment factors. The two inter-row spacings were used not to make differences in planting density but to vary the spatial plant distribution in the field. Each plot consisted of 7 rows of 2 m long and 3.5 and 4.9 m wide. All sub-sub-plots were isolated from each other by 1 m and main plots were separated by 1.5 m space. The experimental field was watered two days before planting for uniform germination. Plants in all plots were maintained at optimum moisture level for 2 weeks after emergence whereby irrigation water was applied uniformly to all treatments for uniform stand establishment. After stand establishment (10 cm plant height), plants were subjected to two soil moisture regimes: well watered and dry. Well-watered treatments were maintained above 80% of plant available soil water while the dry treatments were allowed their water content to deplete to 25% plant available soil water before irrigation was applied. Plant available soil water was set as the water content between field capacity (-0.03 MPa) and permanent wilting point (-1.5 MPa). Soil moisture content of the top 15 cm was monitored at 3 to 4 days interval on a volume/volume basis by a portable Time Domain Reflectometry probe (TRIME-system, IMKO GmbH, Germany). When moisture reached at the specified levels (80 and 25% available soil water), plots were irrigated and restored to field capacity. Irrigation was continued as needed throughout the growth period according to the specified watering levels. One main canal, running between main plots, supplied water to the plots by furrow irrigation. The canals were lined with polyethylene sheet to avoid unintended watering from seepage. Manually operated mobile rainout shelters that could be taken on and off protected dry treatments from rainfall. The shelters, 4.6 m wide and 11.8 m long, were placed to cover the entire main plots. The design of the shelter consisted of a wooden support frame of 1.2 m high. This frame was permanently installed in the plot. A polyethylene cover was placed on top of the support frame whenever rain was expected. Side flaps were also prepared to be rolled down to avoid entry of rain from the sides.

The number of irrigation applications varied with treatment, but ranged from twenty-seven for the well-watered treatment to eight for the dry treatment (Table 1). The irrigation application depths were determined based on soil water storage capacity and depletion level. Under no-stress conditions, irrigation was applied when the available soil moisture in the root zone was depleted to 80% of the total available soil moisture (20% depletion). In stress conditions, irrigation was applied whenever soil moisture content was depleted to 25% of the total available soil moisture in the root zone (75% depletion). The irrigation application depth was calculated based on the following formula (Allen *et al*., 1998):

$$TAW = 1000\,(\theta_{FC}-\theta_{Wp})Z_r$$

Where:

TAW = The total available soil water in the root zone (mm)

θ_{Fc} = The water content at field capacity (m^{-3})

θ_{Wp} = The water content at wilting point (m^{-3})

Z_r = The rooting depth (m)

Table 1: Mean cumulative water use from emergence to maturity, growth duration, irrigation frequency and interval during the growing period

Moisture regime	Cumulative water use (mm)	Growth duration (days)	No. of irrigations	Irrigation interval (days)
Wet	554	103	27	4
Dry	365	99	8	12

Plants under the dry regime received 34% less water compared to the wet regime, on average (Table 1). The 554 mm cumulative water use in the wet regime can be considered as an optimum supply required` for maximum sole cowpea production under the test environment.

Two central rows with an area of 2 and 2.8 m^2 (2×1 m and 2×1.4 m) were harvested at maturity for determination of grain yield, yield components and total biomass. Grain yield was adjusted to 12.5% moisture content. Number of pods per plant and per unit area were determined from 10 randomly selected plants while number of grains per pod was averaged from 20 randomly sampled pods. Grain weight was determined by randomly taking 100 grains from the harvested grain for yield and weighing it with sensitive balance after oven drying to constant weight. Harvest index was calculated as the ratio of grain yield to above ground biomass.

The data were analyzed using the GLM procedure of the SAS statistical software (SAS Institute, 2000) appropriate for the design. Means were separated using Fisher's Least Significant Difference (LSD) test at $p< 0.05$. Correlation analysis was made with Pearson's simple correlation coefficients using treatment mean values (n = 16).

RESULTS AND DISCUSSION

Grain yield: Well-watered plants produced significantly higher grain yield per area (4.76 t ha^{-1}) than dry treatments (3.08 t ha^{-1}), showing a 54.5% increase (Table 2, 3). Grain yield per plant also responded in a similar way to watering regime. The grain yield loss due to water limitation was 8.9 kg ha^{-1} for each mm of water shortage. Limited moisture may have hindered plants from growing to their full capacity thereby affecting their productivity. For instance, water stressed plants attained low leaf area index, less number of branches (data not shown), lower number of pods per plant and per unit area, smaller number of grains per pod, lighter grain weight and reduced harvest index. This consequently led to a significantly lower grain yield under the dry water regime. Similarly, Crafurd and Wheeler (1999) and Herbert and Baggerman (1983) observed a negative response of cowpea to limited irrigation. Worku and Skjelvåg (2006) in common bean indicated that the loss of grain yield from water stress is mainly associated with reduced light interception as a result of restricted canopy size. Inter-row spacing affected neither grain yield per plant nor grain yield per area. Similarly, none of the yield components were affected by inter-row spacing. On the other hand, Herbert and Baggerman (1983) reported highest grain yield with a combination of high density with wide row

Table 2: Mean square values for grain yield, yield components, total biomass and harvest index of cowpea as affected by watering regime, row spacing and planting density

Treatment	df	Grain yield plant^{-1}(g)	Grain yield ha^{-1} (t)	Pod No. plant^{-1}	Pod No. (m^{-2})	Grain No. pod^{-1}	100 grain wt. (g)	Total biomass ha^{-1} (t)	Harvest index
Replication (R)	2	22.6	0.058	30.3	651	0.43	0.085	1.04	0.002
Watering regime (W)	1	2395.4***	33.776***	3402.0***	432941***	51.00**	23.520*	77.74***	0.041*
Error a	2	4.1	0.004	15.7	181	0.11	0.422	0.06	0.001
Row spacing (S)	1	75.8	0.083	26.7	529	4.75	0.007	0.48	0.002
W*S	1	5.2	0.183	19.0	70	2.43	1.203	0.12	0.002
Error b	4	11.3	0.277	23.3	582	0.31	0.621	0.34	0.004
Density (D)	3	1719.7***	0.053	1842.7***	2406***	3.63***	0.285	0.59	0.009***
W*D	3	13.1	1.709**	98.2**	9142***	0.14	0.384	4.88***	0.002
S*D	3	19.5	0.041	7.5	490	0.16	0.203	0.28	0.002
W*S*D	3	3.2	0.073	5.2	4653***	0.44*	0.112	0.62	0.001
Error c	24	9.4	0.100	16.1	276	0.14	0.612	0.43	0.001

df: Degree of freedom; *, **, ***indicate significance at 0.05, 0.01 and 0.001 probability-levels, respectively

Table 3: Grain yield, yield components, total biomass and harvest index of cowpea as affected by watering regime, row spacing and planting density

Treatments	Grain yield plant^{-1}(g)	Grain yield ha^{-1} (t)	Pod No. plant^{-1}	Pod No. (m^{-2})	Grain No. pod^{-1}	100 grain wt. (g)	Total biomass ha^{-1} (t)	Harvest index
Watering regime								
Well watered	39.37a	4.76a	38.38a	456.73a	14.47a	9.67a	10.01a	0.45a
Dry	25.24b	3.08b	21.55b	266.78b	12.41b	8.27b	7.47b	0.39b
LSD$_{0.05}$	2.53	0.08	4.92	16.73	0.41	0.80	0.31	0.04
Row spacing								
50 cm	31.04	3.96	29.22	365.08	13.12	8.99	8.84	0.43
70 cm	33.04	3.88	30.71	358.44	13.75	8.96	8.64	0.42
LSD$_{0.05}$	NS	NS	NS	NS	NS	NS	NS	NS
Planting density (plants ha^{-1})								
71428	47.22a	3.91	46.71a	376.42a	14.10a	9.03	8.78	0.46a
95238	35.33b	3.88	30.39b	350.52b	13.55b	9.08	8.49	0.43ab
133333	27.63c	4.01	25.43c	371.32a	13.34b	9.05	9.02	0.41bc
200000	19.02d	3.86	17.33d	348.77b	12.77c	8.70	8.67	0.40c
LSD$_{0.05}$	2.58	NS	3.38	14.02	0.32	NS	NS	0.032

Means with the same letter(s) within columns are not significantly different at 0.05 probability level; NS: Not significant

spacing while lowest yield was achieved at high density in narrow row spacing indicating a spacing × density interaction. Ball *et al*. (2000a) also indicated that yields among row spacings were generally greater as row spacing decreased. One possible reason for the difference with our results could be the smaller interval we used between the two spacings as compared to the interval from earlier studies. For instance, Herbert and Baggerman (1983) used five levels between 25 and 125 cm while Ball *et al*. (2000a) used 19, 57 and 95 cm row widths against our 50 and 70 cm spacings.

The effect of planting density was not significant on grain yield ha^{-1} (Table 2). This was because the response of grain yield per area to planting density under the wet and dry water regimes showed a contrasting trend. It was evident from the significant interaction between planting density and water regime for grain yield per area (Table 2, Fig. 2).

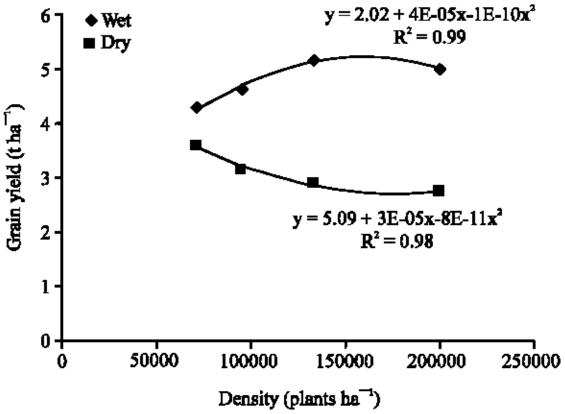

Fig. 2: Interaction effect of moisture and planting density on grain yield ha^{-1} of cowpea

The interaction showed that under well-watered conditions, increasing plant density from 71428 to 133333 plants ha^{-1} increased grain yield ha^{-1} from 4.26 to 5.15 t ha^{-1} while further increase to 200000 plants ha^{-1} decreased grain yield. Grain yield plateau was reached at the estimated density of 160000 plants ha^{-1} with a maximum yield of 5.24 t ha^{-1}. On the other hand, increasing plant density from the lowest (71428 plants ha^{-1}) to the highest density (200000 plants ha^{-1}) decreased grain yield continuously, under the dry regime. Drought aggravated the competition among plants for moisture leading to declining productivity with increasing densities. Ball *et al*. (2000b) examined the response of soybean (*Glycine max* L.) to planting density under irrigated and non irrigated conditions. They reported an asymptotic yield response to rising levels of planting density between 7 and 134 plants m^{-2} in both irrigated and non irrigated crops. Moreover, Craufurd and Wheeler (1999) made a similar study on cowpea at densities of 2, 4, 6, 8 and 10 plants m^{-2} and observed an increasing yield response to increasing density in both the stressed and well watered conditions. No water×density interaction was reported in both studies and the discrepancy to present results could probably be due to differences in type of cultivars used, level and duration of stress and planting density ranges.

The interaction shows that producers can optimize their yield especially under drier environments by adjusting their planting density. Using a similar 160000 plants ha^{-1} density, which is optimum for the wet regime, will cause an estimated yield loss of 30% under the dry regime. Conversely, maintaining the optimum density of the dry regime (71428 plants ha^{-1}) under the wet regime will cause a yield loss of 19% in the wet regime. Thus, by using compatible planting densities with the expected moisture supply, it is possible to enhance productivity without incurring additional cost. Under a more severe water stress, it is likely that the variation in optimum planting density could be even greater to that of optimum moisture. The advantage of matching density with moisture supply is many fold because it also cuts unnecessary seed and crop establishment expenses.

The cowpea yield obtained in our experiment is high, which is at par or greater to reported yield levels and this substantiates the suggestion of Singh *et al.* (1997). They indicated that cowpea has a great potential for increasing food legume production if grown as a sole crop. Singh *et al.* (1997) also observed that if early maturing erect and semi erect varieties are grown as pure crop with required inputs, cowpea has the potential of yielding as high as cereals on a productivity per day basis.

Yield components: Dry treatments produced smaller number of pods per plant and per area than did the well watered treatments (Table 2, 3). Pod number per plant in the dry treatment was 21 while it was 38 in the wet treatment showing a reduction of 44%. Number of pods per m^{-2} was also decreased from 456 to 288 for a similar comparison, showing a 37% loss. It may be reasoned that the relatively greater leaf area index and longer plant height (data not shown) of well-watered plants might have enabled the crop to accumulate more dry matter and greater reproductive sink capacity. This result was similar to those of Pandey *et al.* (1984), who obtained reduced number of pods per plant in mung bean (*Vigna radiata* L. Wilczek), cowpea, soybean and peanut (*Arachis hypogaea* L.) in the driest compared to the wettest treatment. In addition, pod number per plant of common bean was significantly reduced by terminal and season long water stress (Worku and Skjelvåg, 2006).

Planting density significantly affected number of pods per plant and per area differently (Table 2, 3). Number of pods per plant decreased as the plant density increased. The highest number of pods per plant (46.7) was recorded from the lowest planting density and the smallest number of pods per plant (17.3) was obtained from the highest planting density. Ali *et al.* (2001) also observed that the lowest seed rate (20 kg ha^{-1}) produced less number of plants per unit area resulting in favorable conditions for space, light and air leading to better pod formation in rice bean (*Vigna umbellata*). Increased abortion of reproductive parts in the lower canopy layer may also have caused the low number of pods per plant in densely populated plants. This could be attributed to the enhanced mutual shading at the highest planting density. Worku *et al.* (2004) found that low irradiance during flowering caused a high proportion of aborted flowers in common bean leading to low number of pods per plant. A significant density×moisture interaction for pod number per plant showed a slight tendency for differences between wet and dry regimes to be wider at lower densities. Although, pod number per plant was reduced as density increased, grain yield was more than compensated by the greater number of plants m^{-2} contributing more number of pods on per unit area basis. As a result yield increased with rising planting density, especially under the wet regime. In spite of a significant density effect on pod number per area, there was no clear trend for it among the various density levels. This lack of ranking could be attributed to the variable effects of moisture level on the different plant densities as indicated by a significant moisture× density interaction (Table 2, Fig. 3). The trend of the interaction is quite comparable to what has been observed for a similar interaction on grain yield per unit area. Because number of pods per area is positively correlated with grain yield per area under both wet ($r = 0.68^{***}$) and dry ($r = 0.54^{***}$) moisture regimes. Pod number per area increased with rising planting density up to 133333 plants ha^{-1} under the wet regime but a further density increase to 200000 plants ha^{-1} reduced it (Fig. 3). On the other hand, pod number per area decreased consistently with increasing planting density under the dry regime. The reduction in pod number per area with rising planting density for the dry treatment was probably due to

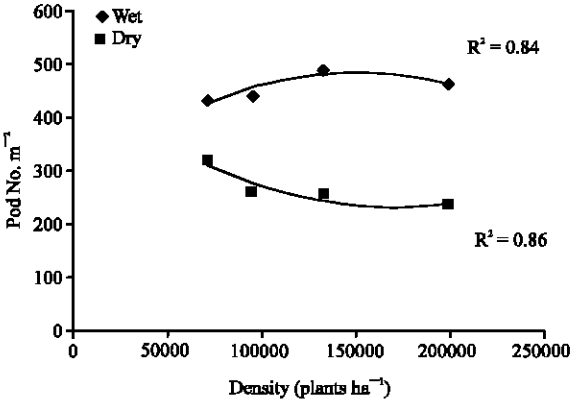

Fig. 3: Interaction effect of moisture and planting density on pod No. m^{-2} of cowpea

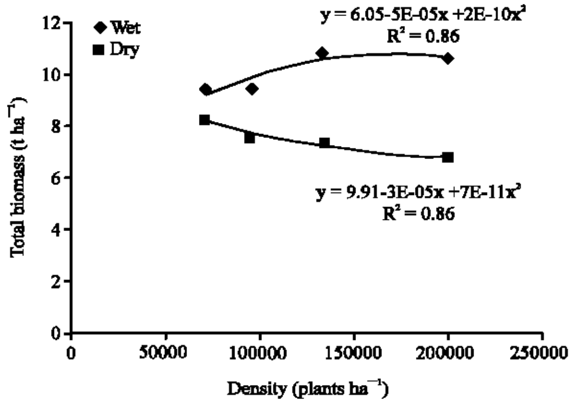

Fig. 4: Interaction effect of moisture and planting density on total biomass yield ha^{-1} of cowpea

reduced flower production and greater abortion of flowers following aggravated competition for moisture.

The dry treatment produced 14% less number of grains per pod compared to the wet treatment. Number of grains per pod decreased with rising planting density, generally (Table 3). The difference in number of grains per pod between the lowest (71428 plants ha^{-1}) and the highest density (200000 plants ha^{-1}) was 9.5%. These are smaller reductions compared to number of pods per plant for similar comparisons indicating the greater role of pod number per plant in explaining the variability in yield. These results are in agreement with that of Jahan and Hamid (2004) in mung bean and Ali *et al.* (2001) in rice bean who observed a decrease in number of grains per pod with increasing seed rates. A three factor interaction among watering regime, inter-row spacing and planting density affected pod number per area and grain number per pod. However, as long as grain yield per area is not statistically significant for the same interaction ($p = 0.5455$), the importance of this interaction is rather small.

Except watering regime, none of the main effects and their interactions were significant in affecting grain weight of cowpea (Table 2). The dry treatment had significantly reduced grain weight compared to the wet treatment by 14% (Table 3). The reduction is comparable to grain number per pod but very much lower than pod number. Similarly, Pandey *et al.* (1984) observed reduced grain weight in soybean, peanut, cowpea and mungbean by 24, 16, 10 and 4%, respectively, in dry compared to wet treatments. Regarding density levels, Ball *et al.* (2000b) did not detect a difference in grain weight among eight density levels between 7 and 91 plants m^{-2}, in soybean. Over all, it seems that the plant adjusts its sink size to an environment that prevails from the beginning primarily by modifying its number of pods per plant.

Biomass yield: Biomass yield decreased significantly from 10.0 to 7.4 t ha^{-1} as moisture reduced from well watered to dry, showing a drop of 30% (Table 2, 3). Similarly, several researchers reported reduced biomass yield due to water stress (Craufurd and Wheeler, 1999; Worku and Skjelvåg, 2006). The reduced biomass yield could be attributed to the impact of low moisture supply on the assimilatory area as evidenced by a positive correlation of leaf area index with biomass production (r= 0.48*). Moreover, the shorter growth duration observed under the dry regime contributed to the decreased biomass yield. A significant positive correlation between biomass yield and days to maturity (r = 0.77***) was observed.

Biomass yield was influenced by a significant moisture x density interaction, which was similar to grain yield (Table 2, Fig. 4). The interaction indicated that biomass yield per area increased with increasing planting density up to 170000 plants ha^{-1} under well-watered conditions, whereas a consistently decreasing trend was observed for the dry regime with rising planting density. The total biomass yield plateau of 10.9 t ha^{-1} was reached at 170000 plants ha^{-1}. This is a higher density level compared to grain yield because of a moderate drop in harvest idex with rising density. The result for the wet treatment is in agreement with that of Ali *et al.* (2001), who observed that biological yield was increased with the rise in seed rate under favorable conditions, in rice bean.

Harvest index: Harvest index was significantly affected by watering regime and density but not by inter-row spacing (Table 2). It was reduced from 0.45 to 0.39 due to water limitation showing a 13% decline. The reduction in harvest index suggests that grain yield is more sensitive to water stress than total plant yield. This is in agreement with the findings of Pandey *et al.* (1984), who observed that harvest index declined as water application decreased in four legume species. Similarly, lower harvest indices were recorded under sub-optimal moisture supply in soybean (Ball *et al.*, 2000b) and in cowpea (Herbert and Baggerman, 1983).

There was a decreasing of harvest index with increasing planting density, in general (Table 3). Ismail and Hall (2000) observed that low plant density tended to increase harvest index in cowpea. On the other hand, Ball *et al.* (2000b) reported that differences in harvest index among planting densities were generally confined to the highest density (134 plant m^{-2}) when there was lodging, in soybean. With increased plant density levels, changes may occur in the allocation of assimilates to different parts of the plant. As a result, a greater proportion of the reproductive parts of an individual plant may become barren causing a decline in grain production whereas the total dry matter production may remain constant (Turk and Hall, 1980).

CONCLUSION

Present experiment has shown an interaction between moisture and planting density indicating the importance of adjusting density levels to available moisture supply. For optimum moisture supply conditions as high as 160000 plants ha^{-1} could be used for similar growth habit cultivars while in a semiarid area about 70000 plants ha^{-1} could be sufficient. Under a more severe water stress, it is likely that the variation in optimum planting density could be even greater in comparison to optimum moisture supply. Further test is needed if lower densities would still give a better yield under the dry regime. The estimated optimum yield of 5.21 t ha^{-1} under the wet regime indicated that sole cowpea could serve as a meaningful alternative to the other high yielding crops. Neither grain yield nor its components responded to inter-row spacing. Thus, it is possible to use the two spacings interchangeably by choosing whichever is convenient for management.

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