Effects of plant density on yield parameters of cowpea (Vigna unguiculata L.)

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Abstract
Cowpea (Vigna unguiculata L.) is an important pulse, fodder and green manure crop. In symbiotic association with Rhizobium bacteria, cowpea fixes atmospheric dinitrogen in its root nodules. Hence cowpea forms an integral part of the cropping systems in Indian agriculture. A field experiment was conducted during rabi 2018-19 on a sandy loam soil of Bagusala Farm (23°39’ N latitude, 87°42’ E longitude), M. S. Swaminathan School of Agriculture, Gajapati District, Odisha, to study the effects of variety, plant spacing and variety x spacing interaction on the yield components of cowpea. The experiment was conducted in a split plot design with three replications. Three cowpea varieties, Ketaki, Kamini, and Gomati, were the main plots and three within row plant spacings of 10, 15 and 20 cm, corresponding to plant population densities of 333333, 222222 and 166666 plants ha\(^{-1}\) were the split plots, forming a total of nine treatment combinations. The seeds of cowpea were sown in rows on ridges spaced 30 cm apart. At harvest the yield attributes, pod length, pods plant\(^{-1}\), grain yield, 100 grain weight, biological yield, stover yield and harvest index were recorded. The three cowpea varieties tested did not differ significantly in pods plant\(^{-1}\) and pod length but differed in 100 grain test weight. Gomati had the highest grain test weight, followed by Ketaki, with Kamini having the least test weight. Higher grain yield was recorded in the widest spacing of 20 cm compared to the closest spacing of 10 cm. Cowpea varieties, plant spacings and variety x spacing interactions did not have significant effects on stover yields and harvest indices. The widest plant spacing of 20 cm had higher benefit-cost ratio (BC ratio) than the closer spacings of 10 and 15 cm which had similar BC ratios. Variety x spacing interactions affected BC ratio.

Keywords: Cowpea, grain yield, harvest index, plant spacing, population density, stover

Introduction

Highlights
- Higher grain yield was recorded in the widest spacing of 20 cm compared to the closest spacing of 10 cm.
- The widest plant spacing of 20 cm had higher benefit-cost ratio than the closer spacing of 10 and 15 cm which had similar BC ratios.

Pulses are important sources of proteins, vitamins, and minerals for the predominantly vegetarian population of India. Besides, pulse crops fix dinitrogen of the atmosphere in their root nodules in symbiotic association with Rhizobia bacteria and enrich soil fertility. Therefore, they form an integral part of the cropping systems in Indian agriculture. India is the largest producer and consumer of pulses in the world. The production of pulses in India is 25.23 million tonnes and the projected demand by the year 2030 is 35 million tonnes (Farmer Portal, 2018) \(^{[2]}\). Pulse production in India is not commensurate with the demand in the country. There has been stagnation in the production and productivity of pulses over the past three decades. This is mainly due to the low yield potential of legumes under irrigation, instability of yields and diversion of acreage from pulses to cereals. The important grain legumes grown in India are bengalgram, lentil, greengram, blackgram, cowpea, redgram and peas. Among grain legumes, cowpea (Vigna unguiculata L.) is an important crop in the arid and semi-arid tropical regions. The green pods of cowpea are used as vegetable. In addition to grain, it is also grown for its nutritious fodder. Cowpea is grown as...
catch crop, mulch crop, intercrop, mixed crop and green
manure crop. It has the ability to fix atmospheric nitrogen in
soil at the rate of 56 kg per ha in association with symbiotic
bacteria under favorable conditions (Yadav, 2003) [8]. Cowpea
is often grown as a green manure crop for soil improvement.
The crop has rapid and luxuriant vegetative growth and
covers the ground so well that it checks soil erosion and also
weeds and can later be ploughed into the soil as green
manure. It has considerable promise as a pulse crop in dry
land farming and sustainable agriculture.
Cowpea is a warm weather crop grown and is grown in the
semi-arid tropics. Day temperature of 27°C and night
temperature of 22°C are considered optimum for cowpea
cultivation. In India, cowpea is grown in an area of 3.9
million ha with a production of 2.21 million tonnes. In
Odisha, the crop is grown in an area of 1.5 million ha with a
production of 0.49 million tonnes. The productivity of cowpea
in Odisha is low (420 kg/ha) compared to the national
productivity of 567 kg ha⁻¹. This clearly indicates the
necessity for research to improve cowpea productivity in
India in general and Odisha in particular.

Plant population density is a key factor affecting growth and
yield of crops. High population densities may affect light
interception, nutrient uptake and water availability of crops.
Optimum population densities for different crop varieties
need to be determined in different agroclimatic zones and soil
types to improve crop productivity. It is the most important
non-monetary input, which can be manipulated to attain
maximum production per unit area. The present study was
undertaken during the rabi season of 2018-19 to study the
effects of intra-row spacing on the yield components of three
cowpea varieties and to determine the optimum plant
population densities for the cowpea varieties to maximize
grain yield on sandy loam soils in Gajapati District of Odisha.

Materials and methods
Experiment Site and Design
A field experiment was conducted during rabi season of
2018-19 in the Instructional Farm of Centurion University,
Bagusala village (23°39’ N latitude, 87°42’ E longitude),
Gajapati district, Odisha, under typical sub-humid and sub-
tropical climatic conditions. The soil was a sandy loam, where
the percentages of sand, silt and clay were 55.2, 20.4 and
18.5, respectively. The soil pH was 6.2, EC 0.35 dS m⁻¹ and
organic carbon 0.31%. During the period of experimentation,
the minimum and maximum temperature ranged from 18°C
and 35°C, respectively and the crop received rainfall of 16.36,
4.43 and 0.08 mm during the months of December, January
and February, respectively.
The experiment was conducted in a split plot design with
three replications. Three cowpea varieties, Ketaki, Kamini
and Gomati, were the main plots and three within row plant
 spacings of 10, 15 and 20 cm, corresponding to plant
 population densities of 33333, 222222 and 166666 plants ha⁻¹,
were the split plots, forming a total of nine treatment
combinations. The seeds of cowpea were sown in rows on
ridges spaced 30 cm apart. Each plot consisted of 10 rows,
each 3 m long and an area of 9 m².

Experiment procedure
The land was prepared by ploughing twice with a mouldboard
plough and then harrowing, levelling and ridging. Basal
fertilizer was applied at the rate of 25 kg N, 50 kg P₂O₅ and
25 kg K₂O ha⁻¹ in the form of urea, single super phosphate
and muriate of potash, respectively. The cowpea seeds of the
varieties, Ketaki, Kamini and Gomati were sown on 8th
December, 2018 and the field irrigated. Seeds were sown in
rows spaced at 30 cm at a depth of 4 cm. Three seeds were
sown per hill at spacings of 10, 15 and 20 cm. Irrigations were
applied thereafter when needed. Gap filling was undertaken
one week after sowing and thinning was done 15 days after
sowing (DAS), retaining one healthy seedling per hill, to
maintain desired plant population treatments. Two hand
weedicings were done at 15 and 30 DAS. The plants were
harvested after physiological maturity, when the pods turned
yellow, by cutting the plants at ground level. Five randomly
selected plants from each plot were weighed with the help
of a spring balance. Later, the value of the biological yield
of each plot was converted to kg ha⁻¹. After picking, threshing
and winnowing, the grain yield of each plot was weighed
and recorded in kg. The plot yield was later converted to kg/ha⁻¹.
The crop bundle of each plot was weighed and recorded as
per treatment in kg and thereby the stover yield was
recorded for various yield attributes was done using statistical
procedures appropriate for the split plot design and the
variety, spacing, and variety x spacing interaction variances
were tested by the “F” test. Treatment means, standard errors
of means, co-efficient of variation percentages and critical
differences (CDs) at 5% probability level were calculated and
the obtained CD values compared with table values to test
whether the various yield components showed significant
differences amongst treatments.

Observations on yield attributes
At harvest, five pods were collected at random from five
randomly selected plants from each treatment combination
and their lengths measured in cm with a measuring scale. The
filled pods of the selected plants were counted and the mean
pods plant⁻¹ calculated. Random grain samples were drawn
from the threshed and cleaned produce from each plot and
weights of 100 grains were recorded. The harvest produce
from each net plot was tied separately into bundles. The
bundles were sun dried for 2 days and weighed with the help
of a spring balance. Later, the value of the biological yield
of each plot was converted to kg ha⁻¹. After picking, threshing
and winnowing, the grain yield of each plot was weighed and
recorded in kg. The plot yield was later converted to kg/ha⁻¹.
The crop bundle of each plot was weighed and recorded as
per treatment in kg and thereby the stover yield was
calculated as the ratio of economic yield to the biological
total yield and multiplied by 100 to obtain the value as percentage.

Results and discussion
The three cowpea varieties tested did not differ significantly
in pods plant⁻¹ and pod length but differed in 100 grain test
weights (Table 1). Gomati had the highest grain test weight, followed by Ketaki, with Kamini having the least test weight.
Plant spacing affected pods plant⁻¹ and pod length. The wider
spacing of 20 cm resulted in more pods plant⁻¹ and longer
pods than the closer spacing of 10 cm. Varieties did not differ
significantly for pods plant⁻¹ and pod length in each spacing
treatment. However, spacing affected pods plant⁻¹ and pod
length of each variety, with all varieties having the highest
pod numbers and pod lengths in the widest spacing of 20 cm
and least pod numbers and pod lengths in the closest spacing
of 10 cm.
The grain test weight differed significantly between the three
cowpea varieties (Table 1). Gomati recorded the highest test
weight, followed by Ketaki, with Kamini recording the least
test weight. Plant spacing too significantly affected test
weight, with the widest spacing of 20 cm recording the
highest test weight, followed by 15 cm spacing, and the
closest spacing of 10 cm recording the lowest test weight.
Variety x spacing interaction affected 100 grain test weights. The variety Gomati did not differ significantly from Ketaki but had higher test weight than Kamini in 15 and 15 cm plant spacings. At the widest spacing of 20 cm, Gomati recorded the highest test weight, followed by Ketaki, with Kamini recording the least test weight. Each variety showed significant differences in test weight at different plant spacings. The test weight of each variety increased with increase in plant spacing, with highest for each variety being in the widest spacing of 20 cm and the least in the closest spacing of 10 cm.

Plants with wider spacing of 20 cm had more pods plant$^{-1}$, longer pods and greater 100 grain test weight than plants with closer spacing of 10 cm. This may be due to less competition for light, moisture and nutrients associated with wider spacing and thereby having an edge in producing more reproductive parts when compared to higher plant population density. These results are in conformity with finding of Rajesh Kumar et al. (1997) $^5$ and Shiva Kumar et al. (2002) $^6$.

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Grain yield ha$^{-1}$ did not differ significantly among varieties (Table 2). The within-row plant spacings affected grain yields significantly. Higher grain yield was recorded in the widest spacing of 20 cm compared to the closest spacing of 10 cm. Interaction effects of variety x spacing were found to be not significant. The variations in grain yield components may be attributed to varietal differences and variations due to plant population densities. The rate of dry matter accumulation in reproductive parts (pods) indicates the efficiency of a genotype. Similar findings were also recorded by Arnon (1975) $^1$ and Natarajaratnam (1979) $^4$. Further, less competition for light, moisture and nutrients associated with wider spacing had an edge in producing more reproductive parts compared to higher plant density. Similar findings were also reported by Manjappa (1994) $^3$. Cowpea varieties, plant spacings and variety x spacing interactions did not have significant effects on stover yields and also harvest indices (Tables 2 and 3). However, the high stover yields indicate luxuriant vegetative growth of the three cowpea varieties. Cowpea stover has high nutritive value and provides valuable fodder to cattle. The moderate harvest indices ranging from 27.4 to 34.9% indicate the moderate efficiency of the cowpea varieties in diversion of photosynthates and nutrients to the grains.

The three cowpea varieties did not show significant differences in benefit-cost ratio (BC ratio) (Table 3). The widest plant spacing of 20 cm had higher BC ratio than the closer spacings of 10 and 15 cm which had similar BC ratios. Variety x spacing interactions affected BC ratio. Varieties did not differ in BC ratio in each spacing treatment. However, BC ratio of each variety was significantly affected by plant spacing. All varieties had the highest BC ratio in the widest plant spacing of 20 cm and lower and similar BC ratios in the two closer spacings of 10 and 15 cm. Economics is a major criterion to evaluate treatments which are economically sound and that can be accepted by the farming community. In the present study, the maximum BC ratios were realized by all the varieties at the wider plant spacing of 20 cm compared to the closer spacings of 10 and 15 cm. These findings were in conformity with those of Shivananda (2005) $^7$.

<table>
<thead>
<tr>
<th>Variety</th>
<th>10cm</th>
<th>15cm</th>
<th>20cm</th>
<th>Mean</th>
<th>10cm</th>
<th>15cm</th>
<th>20cm</th>
<th>Mean</th>
<th>10cm</th>
<th>15cm</th>
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<tbody>
<tr>
<td>Kamini</td>
<td>8.6</td>
<td>11.5</td>
<td>7.8</td>
<td>9.7</td>
<td>25.9</td>
<td>27.3</td>
<td>27.8</td>
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<td>50.6</td>
<td>51.2</td>
<td>52.5</td>
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<td>12.4</td>
<td>10.4</td>
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<td>27.4</td>
<td>28.2</td>
<td>27.6</td>
<td>50.0</td>
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<td>52.9</td>
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<tr>
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<td>11.3</td>
<td>13.5</td>
<td>11.6</td>
<td>26.6</td>
<td>27.6</td>
<td>29.1</td>
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<tr>
<td>Mean</td>
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<td>10.0</td>
<td>12.4</td>
<td></td>
<td>26.3</td>
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<td>50.8</td>
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</table>

Table 1: Pods plant$^{-1}$, pod length and 100 grain test weight of cowpea varieties at plant spacings of 10, 15 and 20 cm

<table>
<thead>
<tr>
<th>Variety</th>
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<th>15cm</th>
<th>20cm</th>
<th>Mean</th>
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<th>15cm</th>
<th>20cm</th>
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<th>10cm</th>
<th>15cm</th>
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</tr>
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<tbody>
<tr>
<td>Kamini</td>
<td>915</td>
<td>1001</td>
<td>1049</td>
<td>1004</td>
<td>988</td>
<td>3447</td>
<td>2771</td>
<td>3101</td>
<td>3106.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ketaki</td>
<td>960</td>
<td>983</td>
<td>1091</td>
<td>1011</td>
<td>2883</td>
<td>3235</td>
<td>3293</td>
<td>3137.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gomati</td>
<td>982</td>
<td>999</td>
<td>1112</td>
<td>1031</td>
<td>2833</td>
<td>3305</td>
<td>3465</td>
<td>3200.8</td>
<td></td>
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</tbody>
</table>

Table 2: Grain and stover yields (kg ha$^{-1}$) of cowpea varieties at plant spacings of 10, 15 and 20 cm

-346-
<table>
<thead>
<tr>
<th>Variety</th>
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<th>15cm</th>
<th>20cm</th>
<th>Mean</th>
<th>10cm</th>
<th>15cm</th>
<th>20cm</th>
<th>Mean</th>
</tr>
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<tbody>
<tr>
<td>Kamini</td>
<td>27.4</td>
<td>34.8</td>
<td>34.4</td>
<td>32.2</td>
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<td>1.228</td>
<td>1.422</td>
<td>1.254</td>
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<tr>
<td>Ketaki</td>
<td>35.2</td>
<td>30.6</td>
<td>34.9</td>
<td>33.6</td>
<td>1.133</td>
<td>1.184</td>
<td>1.424</td>
<td>1.247</td>
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<tr>
<td>Gomati</td>
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<td>30.9</td>
<td>32.2</td>
<td>33.2</td>
<td>1.134</td>
<td>1.187</td>
<td>1.417</td>
<td>1.246</td>
</tr>
<tr>
<td>Mean</td>
<td>32.9</td>
<td>32.1</td>
<td>33.8</td>
<td>33.2</td>
<td>1.126</td>
<td>1.199</td>
<td>1.421</td>
<td>1.246</td>
</tr>
</tbody>
</table>

**Conclusion**

The wider plant spacing of 20 cm x 30 cm, corresponding to a plant population density of 1,66,666 plants ha⁻¹, may be adopted for the cultivation of the cowpea during rabi in sandy loam soils of Gajapati District, Odisha, as higher cowpea grain yields were obtained compared to the closer and intermediate plant spacings of 10 cm x 30 cm and 15 cm x 30 cm, corresponding to population densities of 3,33,333 and 2,22,222 plants ha⁻¹, respectively. The widest plant spacing of 20 cm had higher benefit-cost ratio (BC ratio) than the closer spacings of 10 and 15 cm which had similar BC ratios. Variety x spacing interactions affected BC ratio.

**References**