*Journal of Experimental Agriculture International*

***Volume 45, Issue 11, Page 49-57, 2023; Article no.JEAI.108806***
***ISSN: 2457-0591***
*(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)*

# Effect of Planting Pattern, Fertilizer Levels and Weed Management Practices on System Productivity and Economics of Pigeonpea-Based Intercropping System

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/JEAI/2023/v45i112234

**Open Peer Review History:**
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here:
https://www.sdiarticle5.com/review-history/108806

***Original Research Article***

***Received: 25/08/2023***
***Accepted: 30/10/2023***
***Published: 01/11/2023***

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## ABSTRACT

The experiment was conducted during *kharif* 2021-22 at Tirhut College of Agriculture, Dholi, a campus of Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar. The primary objective was to assess how different planting pattern, in addition with the varying fertilizer levels along with weed management practices, affected the growth and physiological characteristics of pigeon pea under pigeon pea based intercropping system. The study was laid down by using factorial randomized block design with 2 intercropping systems, 3 fertilizer levels and 4 weed management practices, each replicated three times to reduce the experimental error. The study's results highlighted that all the intercropping system in both the planting pattern recorded significantly higher net return and B:C ratio than sole pigeon pea. Among the intercropping systems, paired row planting of pigeon pea (45 cm) in 2:2 row ratio significantly recorded maximum growth, yield attributes and yield, net return and B:C ratio than their intercropping with pigeon pea in normal planting pattern (60 cm) in 1:1 row ratio and pigeon pea + soybean in both planting pattern. Although, growth, yield and economics increased significantly with subsequent increase in fertilizer levels and recorded higher values up to 100% RDF. Weed management practices recorded significantly higher plant height, yield indices, grain yield, net return and B:C ratio than weedy check. Among weed management practices, hand weeding twice recorded significantly higher growth and yield attributes, fruiting efficiency, grain yield and net return than combined application of imazethapyr with quizalofop ethyl and pre-plant incorporation of chlorimuron ethyl *fb* imazathapyr except number of pods/plant, fruiting efficiency and net return with combined application of imazethapyr + quizalofop ethyl. However, significantly higher B:C ratio was associated with combined application of imazethapyr + quizalofop ethyl. Application of 50% RDF in weed management practices produced significantly higher pigeon pea yield than application of 100% RDF in weedy check. Hence, 50% RDF could be saved by adopting the weed management practices in pigeon pea.


*Keywords: Planting pattern; growth; physiological characteristics; N-P-K fertilizer; fruiting efficiency.*

## 1. INTRODUCTION

In India, pigeon pea is grown in an area of about 4.24 mha and produce 3.68 mt of grain with productivity of 832 kg/ ha. However, in Bihar it is grown in an area of 21.50 thousand hectare and produce 32.90 thousand tons of grain with productivity of 1532 kg/ ha [1]. Long duration pigeon pea is widely cultivated in Bihar mostly on marginal and sub-marginal land without any fertilizer under rainfed condition. Under rainfed conditions, the yield of crop is not stable and uneconomical due to the monsoon and their vagaries. Due to initial slow growth rate, low productivity, and long duration of pigeon pea make it uneconomical to grow as a sole crop. Weeds compete heavily with the crop because of its slow growth and the space between inter-row was not utilized efficiently [2]. The strategic placement of rows for both the main crop and intercrops, in the right proportions, holds significant promise in making efficient use of natural resources like space, nutrients, sunlight, and soil moisture. This approach not only maximizes resource utilization but also amplifies overall system productivity [3].

Applying the recommended dose of fertilizer in crop cultivation is of paramount importance for several reasons. Firstly, it ensures that plants receive the essential nutrients they need to thrive, promoting robust growth and higher yields. Secondly, it helps to maintain soil fertility over the long term, preventing nutrient depletion and soil degradation [4]. Properly balanced fertilization can also minimize the risk of nutrient runoff, which can be harmful to the environment [5]. Additionally, applying the right amount of fertilizer saves farmers money by avoiding overuse of costly inputs [6]. In a world where food security and sustainable agriculture are pressing concerns, adhering to recommended fertilizer doses plays a critical role in optimizing crop production while safeguarding the environment and economic sustainability in the agricultural sector [7].

Implementing the right weed management methods in crop cultivation is indispensable for the success of agriculture [8]. Weeds compete with crops for essential resources such as water, nutrients, and sunlight, potentially reducing yields and the quality of the harvest. Furthermore, weeds can serve as hosts for pests and diseases, creating additional challenges for farmers. Effective weed management not only enhances crop productivity but also reduces the need for herbicides, which can have ecological and economic implications [9]. By utilizing the appropriate weed control strategies, farmers can promote sustainable and environmentally friendly farming practices, preserving the long-term health of the soil and reducing the environmental impact of agriculture [10]. In a world where food production needs to meet the growing demands of a growing population while minimizing adverse environmental effects, the implementation of proper weed management techniques is pivotal for the future of agriculture. To tailor nutrient management strategies for pigeon pea-based intercropping systems in Bihar's rainfed conditions, this study was undertaken. To assess the impact of planting pattern, fertilizer levels and weed management practices on productivity and economics of pigeon pea based intercropping system in different planting pattern in 2021-2022.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site and Treatment Details

The field experiment was conducted at Tirhut College of Agriculture, Dholi (25$^{o}$ 98′N 85$^{o}$ 76′E and an altitude of 51.3 m above mean sea-level) of the Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar during the *kharif* season in 2021- 2022. The experimental site soil was sandy loam in texture, low in organic carbon (0.33%), low in available nitrogen (163.8 kg/ ha) and phosphorus (12.2 kg/ ha) and medium in available potassium (152.8 kg/ ha) with pH 8.4. The experiment was designed out in randomized block design (Factorial) and replicated thrice. The variety of pigeon pea was 'Rajendra Arhar 1', soybean 'P 1241 TL' and urdbean 'Pant U-31' were sown in last week of July. Sole crop of pigeon pea was sown in row 60 cm apart, soybean 45 cm apart and urdbean 30 cm apart. The plant-to-plant distance of 20, 5 and 10 cm was maintained in pigeon pea, soybean and urdbean respectively in sole as well as in intercropping. The recommended dose of fertilizer, i.e., pigeon pea (20:40:20:20 kg NPKS/ ha), soybean (25:25:20 kg NPK/ ha), urdbean (20:40:20 kg NPK/ ha) were given to sole crop. In intercropping systems, fertilizers of intercrops were applied as per treatment along with RDF of pigeon pea. Full dose of N, P, K and S were applied at the time of sowing in pigeon pea, soybean and urdbean. Fruiting efficiency was worked out by dividing the flower-bearing pods by total number of flowers multiplied by 100. Net return was calculated by subtracting cost of cultivation from gross return. Benefit: cost ratio was calculated by dividing the net returns by cost of cultivation. Data pertaining to each attribute were analyzed statistically by applying the standard procedure of randomized block design [11]. Treatment details were given in Table (1).

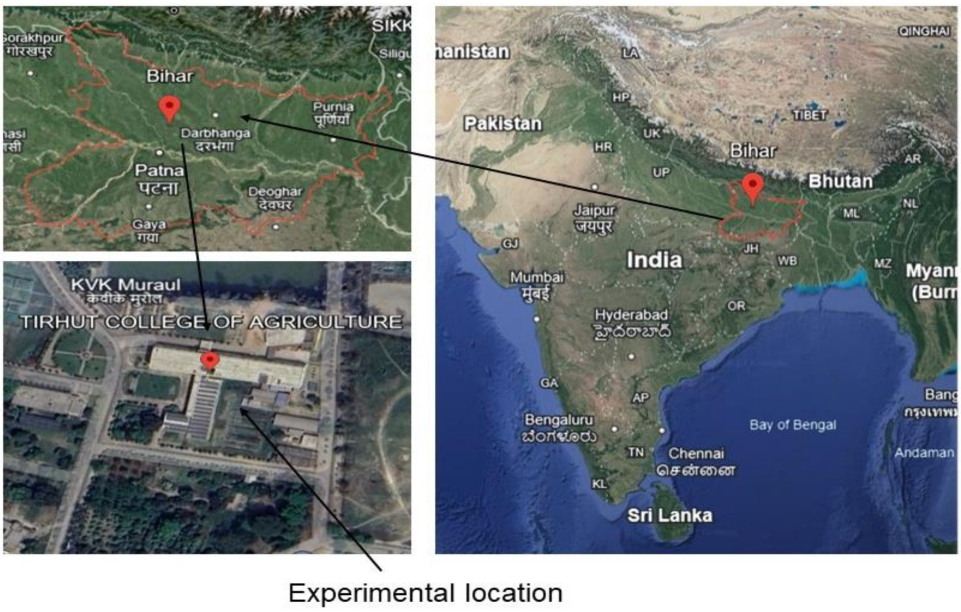


**Fig. 1. Experimental location**

**Table 1. Details of the treatment**

| Symbol | Treatment details |
|---|---|
| **Intercropping system** | |
| $S_0$ | Sole crop |
| $S_1$ | Pigeon pea (60 cm) + soybean (1:1) |
| $S_2$ | Pigeon pea (60 cm) + urdbean (1:1) |
| $S_3$ | Pigeon pea paired (45 cm) + soybean (2:2) |
| $S_4$ | Pigeon pea paired (45 cm) + urdbean (2:2) |
| **Fertilizer levels (intercrops)** | |
| $F_1$ | 50% RDF |
| $F_2$ | 75% RDF |
| $F_3$ | 100% RDF |
| **Weed management practices** | |
| $W_0$ | Weedy check |
| $W_1$ | Hand weeding (20 and 40 DAS) |
| $W_2$ | Imazathapyr (75 g) + quizalofop ethyl (60 g) at 25 DAS |
| $W_3$ | Chlorimuron ethyl (6 g) PPI *fb* imazathapyr (75 g) at 25 DAS |

## 3. RESULTS AND DISCUSSION

### 3.1 Growth and Yield Indices of Pigeon Pea

Plant height did not vary significantly in intercropping system and sole pigeon pea. Plant height of pigeon pea was maximum in pigeon pea + urdbean in paired row planting was at par with pigeon pea + soybean in 2:2 ratio and intercropping and significantly higher than their normal planting pattern (Table 2). Application of 50% RDF recorded significantly lower plant height than 75% and 100% RDF. Maximum plant height was recorded in hand weeding twice which was at par with combined application of imazathapyr + quizalofop ethyl and pre-plant incorporation of chlorimuron ethyl *fb* imazathapyr. This was might be due to period by not allowing weeds to grow during critical periods of crop-weed competition. Similar result has been reported by Dhane et al. [12].

Yield indices such as number of branches and pods/plant recorded significantly higher values in pigeon pea + urdbean in both planting pattern than pigeon pea + soybean and sole pigeon pea (Table 1). Among the planting pattern, paired row planting of pigeon pea + urdbean in 2:2 ratio recorded significantly higher number of branches/ plants, pods/ plant and fruiting efficiency which was significantly superior over other intercropping systems. However, pod length was not significantly affected among the row ratios of intercropping systems and sole pigeon pea. The increased yield indices can be attributed to the reduced competition between the main crop and intercrops for vital growth resources like nutrients and solar radiation. Additionally, the addition of rows of intercrops between the paired rows creates a favorable environment initially by smothering effect on weed and on later stage facilitate penetration of light to lower horizon effect. This conducive setting ultimately leads to the higher expression of these yield indices. [13] found the similar result. These yield indices were also significantly enhanced at 100% RDF than 75% and 50% RDF. This might be due to addition of additional quantities of nutrient in the soil which reduce the state of competition for nutrients among the crop plants and make their availability in appropriate amount to the crop plant resulting in favorable increase in plant height and yield indices. Hand weeding twice recorded maximum pods/ plant and fruiting efficiency which was found at par with combined application of imazathapyr with quizalofop ethyl and significantly higher than pre-plant application of chlorimuron ethyl *fb* imazathapyr. However, number of branches were significantly higher in hand weeded plot. As a result of hand weeding, higher yield attributing parameters were achieved, as weeds were completely eradicated, which enabled better plant growth and more branches. In contrast, these yield components were adversely affected by weedy checks. Due to heavy weed infestations and more competition between crops and weeds. It may have been because herbicidal and cultural treatments (hoeing) reduced dry matter production by weeds, which then increased nutrient and moisture availability. There have been similar results reported by Gupta and Saxena [14] as well as Dhane et al. [15].

**Table 2. Effect of planting patterns, nutrient management and weed management practices on plant height and yield indices of pigeon pea based intercropping system**

| Treatment | Plant height (cm) | Branches/ plant | Pods/ plant | Pod length (cm) |
|---|---|---|---|---|
| **Intercropping system** | | | | |
| Sole pigeonpea | 279.7 | 18.93 | 223.5 | 4.93 |
| Pigeonpea (60 cm) + soybean (1:1) | 273.9 | 17.76 | 220.9 | 4.86 |
| Pigeonpea (60 cm) + urdbean (1:1) | 281.9 | 19.28 | 226.0 | 4.88 |
| Pigeonpea (45 cm) + soybean (2:2) | 295.9 | 20.72 | 232.2 | 4.91 |
| Pigeonpea (45 cm) + urdbean (2:2) | 301.8 | 22.30 | 242.0 | 5.08 |
| **SEm (±)** | **4.2** | **0.28** | **3.1** | **0.07** |
| **CD (p = 0.05)** | **11.8** | **0.79** | **8.7** | **NS** |
| **(Sole vs Rest) SEm (±)** | **21.2** | **0.70** | **7.7** | **0.17** |
| **CD (p = 0.05)** | **NS** | **NS** | **NS** | **NS** |
| **Fertilizer levels (intercrops)** | | | | |
| 50% RDF | 278.5 | 17.86 | 221.8 | 4.90 |
| 75% RDF | 285.4 | 20.37 | 230.2 | 4.93 |
| 100% RDF | 301.3 | 21.82 | 238.8 | 4.97 |
| **SEm (±)** | **3.6** | **0.24** | **2.7** | **0.06** |
| **CD (p = 0.05)** | **10.2** | **0.68** | **7.5** | **NS** |
| **Weed management practices** | | | | |
| Weedy check | 268.7 | 17.16 | 214.5 | 4.78 |
| Hand weeding (20 and 40 DAS) | 305.0 | 22.46 | 240.7 | 5.00 |
| Imazathapyr (75 g) + quizalofop ethyl (60 g) at 25 DAS | 294.8 | 20.79 | 235.6 | 4.99 |
| Chlorimuron ethyl (6 g) PPI *fb* imazathapyr (75 g) at 25 DAS | 285.0 | 19.65 | 230.2 | 4.96 |
| **SEm (±)** | **4.2** | **0.28** | **3.1** | **0.07** |
| **CD (p = 0.05)** | **11.8** | **0.79** | **8.7** | **NS** |

**Table 3. Effect of planting patterns, nutrient management and weed management practices on fruiting efficiency and yield of pigeon pea based intercropping system**

| Treatment | Fruiting efficiency (%) | Grain yield (kg/ ha) |
|---|---|---|
| Intercropping system | | |
| Sole pigeonpea | 16.83 | 1760 |
| Pigeonpea (60 cm) + soybean (1:1) | 15.89 | 1707 |
| Pigeonpea (60 cm) + urdbean (1:1) | 16.44 | 1848 |
| Pigeonpea (45 cm) + soybean (2:2) | 16.40 | 1917 |
| Pigeonpea (45 cm) + urdbean (2:2) | 18.81 | 1988 |
| **SEm (±)** | **0.30** | **24** |
| **CD (p = 0.05)** | **0.83** | **68** |
| **(Sole vs Rest) SEm (±)** | **0.74** | **60** |
| **CD (p = 0.05)** | **NS** | **NS** |
| Fertilizer levels (intercrops) | | |
| 50% RDF | 15.56 | 1680 |
| 75% RDF | 17.15 | 1887 |
| 100% RDF | 17.94 | 2028 |
| **SEm (±)** | **0.26** | **21** |
| **CD (p = 0.05)** | **0.72** | **59** |
| Weed management practices | | |
| Weedy check | 14.83 | 1351 |
| Hand weeding (20 and 40 DAS) | 18.30 | 2246 |
| Imazathapyr (75 g) + quizalofop ethyl (60 g) at 25 DAS | 17.57 | 2003 |
| Chlorimuron ethyl (6 g) PPI *fb* imazathapyr (75 g) at 25 DAS | 16.82 | 1861 |
| **SEm (±)** | **0.30** | **24** |
| **CD (p = 0.05)** | **0.83** | **68** |

**Table 4. Effect of planting patterns, nutrient management and weed management practices on net return and benefit cost of pigeon pea based intercropping system**

| Treatment | Net return (₹/ ha) | Benefit: cost ratio |
|---|---|---|
| Intercropping system | | |
| Sole pigeonpea | 75634 | 1.41 |
| Pigeonpea (60 cm) + soybean (1:1) | 106418 | 2.23 |
| Pigeonpea (60 cm) + urdbean (1:1) | 117237 | 2.47 |
| Pigeonpea (45 cm) + soybean (2:2) | 127662 | 2.69 |
| Pigeonpea (45 cm) + urdbean (2:2) | 137081 | 2.89 |
| **SEm (±)** | **1766** | **0.04** |
| **CD (p = 0.05)** | **4956** | **0.10** |
| **(Sole vs Rest) SEm (±)** | **4383** | **0.09** |
| **CD (p = 0.05)** | **12266** | **0.25** |
| Fertilizer levels (intercrops) | | |
| 50% RDF | 103048 | 2.15 |
| 75% RDF | 123940 | 2.61 |
| 100% RDF | 139310 | 2.96 |
| **SEm (±)** | **1529** | **0.03** |
| **CD (p = 0.05)** | **4292** | **0.09** |
| Weed management practices | | |
| Weedy check | 82400 | 2.00 |
| Hand weeding (20 and 40 DAS) | 140364 | 2.27 |
| Imazathapyr (75 g) + quizalofop ethyl (60 g) at 25 DAS | 139547 | 3.20 |
| Chlorimuron ethyl (6 g) PPI *fb* imazathapyr (75 g) at 25 DAS | 126087 | 2.83 |
| **SEm (±)** | **1766** | **0.04** |
| **CD (p = 0.05)** | **4956** | **0.10** |

## 3.2 Fruiting Efficiency

Fruiting efficiency of pigeon pea enhanced significantly under pigeon pea + urdbean intercropping system in both the planting pattern than pigeon pea + soybean (Table 3). Among the planting patterns, paired row planting of pigeon pea + urdbean in 2:2 row ratio recorded significantly higher fruiting efficiency (18.81%) than paired row planting of pigeon pea + soybean and their intercropping in normal planting pattern. Fruiting efficiency increased significantly with an increment of fertilizer levels and recorded higher value at 100% RDF (17.94%). Weed management practices exerted significant effect on fruiting efficiency. Hand weeding twice significantly enhanced fruiting efficiency than pre-plant application of chlorimuron ethyl *fb* imazathapyr but was at par with combined application of imazethapyr with quizalofop ethyl. In these treatments, fruiting efficiency could be improved because component crops initially cover the soil surface more thoroughly, suppress weeds, conserve soil moisture, and facilitate the uptake of adequate amounts of nutrients by the main crop plant. This results in a lower rate of flower dropping and an improved pod bearing capacity of the plant.

## 3.3 Grain Yield

Paired row planting of pigeon pea + urdbean and pigeon pea + soybean significantly enhanced grain yield of pigeon pea than intercropping of these crops than their normal planting pattern (Table 3). Among the intercropping systems, pigeon pea + urdbean in paired row planting produced maximum pigeon pea yield (1988 kg/ ha) that was significantly higher than pigeon pea + soybean in both row planting and pigeon pea + urdbean in 1:1 row. Kumar and Kushwaha [16] also reported higher grain yield of pigeon pea under pigeon pea + sesame (2:2) row ratio. Inclusion of urdbean with pigeon pea has been found to reduce soil fertility exhaustion, reduce crop-weed competition at early crop growth stages due to their smothering effects on weed, and also improve soil physical properties to some extent compared with and other intercropping's, leading to an increase in yield indices and finally grain yields. Grain yield of pigeon pea increased significantly with increasing levels of fertilizer and recorded higher grain yield at 100% RDF (2028 kg/ha). The increase in grain yield might be owing to adequate quantities of plant nutrients supplied to the intercrops reduced the state of competition for nutrients among main and intercrops, resulting in favorable increase in yield attributes which led towards an increase in grain yield. Pandey et al. [17] also recorded higher pigeon pea yield at recommended dose of fertilizer over 50% RDF. The effect of different weed management practices on grain yield was significantly greater than weedy check. The maximum grain yield of pigeon pea was recorded in the plot receiving two hand weeding (2246 kg/ha) which was significantly higher than other weed management treatments followed by post-emergence application of imazethapyr with quizalofop ethyl (2003 kg/ ha). This might be due to suppressing weed growth effectively enhancing soil aeration through pulverization of soil and make availability of nutrients to the crop plant leading to expression of better growth and yield indices and finally the grain yield. Yadav and Shaikh [18] and Wadafale et al. [19] have reported similar findings.

### 3.4 Economics

Intercropping in both the planting pattern recorded significantly higher net return and B:C ratio than sole pigeon pea (Table 4). Intercropping of pigeon pea + urdbean in paired row planting and normal planting fetched significantly higher net return and B:C ratio than intercropping of pigeon pea + soybean in paired and normal planting pattern. However, significantly higher B:C ratio was registered in paired row planting of pigeon pea + urdbean over other intercropping. Singh et al. [20] recorded higher net return and B:C ratio in pigeon pea + mungbean intercropping system than sole pigeon pea. Similarly, Pigeon pea (75 cm) intercropped with two lines of black gram recorded the maximum benefit cost ratio [21]. Application of 100% RDF significantly enhanced net return and B:C ratio than 50% RDF. However, B:C ratio increased significantly up to 100% RDF. Higher biological yield of main and component crop at higher fertilizer level was in fact the reasons for higher net return and B:C ratio in this treatment. Pandey and Tiwari [22] also recorded higher monetary returns at 125% RDF in pigeon pea based intercropping system. Among weed management practices, significantly higher net return was recorded in hand weeding twice than pre-plant incorporation of chlorimuron ethyl *fb* imazathapyr being at par with combined application of imazethapyr + quizalofop ethyl. However, significantly higher B:C ratio was recorded in post-emergence application of imazethapyr + quizalofop ethyl than pre-plant application of chlorimuron ethyl *fb* imazathapyr and hand weeding twice. The higher net return and B:C ratio in paired row planting of pigeon pea + urdbean was obviously due to better yield of main as well as component crops. Bali et al. [23] also reported that application of quizalofop-ethyl + hoeing at 35 days after sowing recorded the highest benefit cost ratio. Although the yield was higher in hand weeded plot, the net return and B:C ratio was higher in chemical weeding, the cost investment in hand weeding might be caused such differences.

## 4. CONCLUSION

Paired row planting of pigeon pea +urdbean (45 cm) in 2:2 row ratio recorded higher grain yield, net return and B:C ratio than their normal planting pattern and sole pigeon pea. Among weed management treatments, hand weeding twice (20 and 40 DAS) although resulting in significantly higher pigeon pea grain yield but higher economic returns was associated with combined application of imazathapyr + quizalofop ethyl. Application of 50% RDF in weed management practices produced significantly higher pigeon pea grain yield than the application of 100% RDF in weedy check. Hence, weed management practices could save 50% RDF. The post-emergence application of imazathapyr with quizalofopethyl at 25 DAS, not only led to a superior grain yield but also provided comprehensive control over a wide range of weeds. This approach to weed management holds great promise for cultivation, especially in regions where labor costs are high and time constraints are a significant factor.

## ACKNOWLEDGEMENTS

The Dr. Rajendra Prasad Central Agricultural University, Bihar provided the funding and facilities that were required for the authors to perform this study, and they are grateful for their assistance.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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