Indian Journal of Ecology (2024) 51(3): 603-609
DOI: https://doi.org/10.55362/IJE/2024/4281

Manuscript Number: 4281
NAAS Rating: 5.38

Influence of Land Configuration and Weed Management Options on Soil Properties and Nutrient Uptake by Pigeonpea (*Cajanus cajan* L.)

Avaneesh Kumar, Raj Singh, Teekam Singh, Anchal Dass, M.B. Reddy[1] and Kajal Arora[2]

ICAR-Indian Agricultural Research Institute, New Delhi-110 012, India
[1]ICAR- Indian Veterinary Research Institute, Bareilly-243 122, India
[2]ICAR-Central Arid Zone Research Institute, Jodhpur-342 005, India
E-mail: avaneeshsingh407@gmail.com

Abstract: Experiment was carried-out during *kharif* season of 2020 at research farm of Indian Agricultural Research Institute-New Delhi in three times replicated split- plot design with three land configurations (main-plot) while, six weed management options (sub-plot) to assess the effect of these land configuration and weed management options on soil fertility and nutrient uptake by pigeonpea. Results showed that Broad bed and furrow planting recorded higher N, P and K content (3.19, 0.36, 1.24% and 1.22, 0.22, 1.83% in seed and stalk, respectively) and thereby enhanced their uptake (9.4, 19.6, 9.9% and 10.1, 16.5 and 23.2% in seed and stalk, respectively) over flatbed plating apart from contributing higher organic carbon (OC), available N, P and K in the soil. Among weed management options, two-hand weeding (30 and 60 DAS) recorded enhanced N, P and K uptake by seed and stalk; the increase being 61.3, 76.9, 49.3 and 49.3, 162.0, 65.8%, respectively and maintain higher OC, available N, P and K in soil over weedy-check. However, weed-free condition (twice hand weeding) fetched higher protein content and protein yield. Overall, pigeonpea grown on broad bed and furrow with two hand weeding proved better with respect to OC, available soil nutrients (N, P and K) and their uptake, protein yield as well as in soil microbial properties.

Keywords: Land configuration, Weed management, Soil properties, Nutrient uptake, Pigeonpea

Pulses are staple food crops in several countries where they play a vital role in addressing the nation's food and nutritional security, and also assisting in tackling the environmental challenges. Pulses contribute ~ 9-10 per cent in total food production acting as critical and inexpensive source of proteins, vitamins, dietary fibre and minerals, etc. (Tewari et al 2019). Moreover, they also support the economy of the rainfed regions where they contribute to a more sustainable food system by increasing soil fertility (owing to their ability to fix atmospheric nitrogen and physical structure), providing green vegetables (pods/beans) and fodder for cattle, and fitting well into mixed/intercropping systems, crop rotation, and dry farming (Dass and Sudhishri 2010, Sharma et al 2019).

In India, pigeon pea [*Cajanus cajan* (L.) Millsp.] is the second utmost important pulse crop after chickpea. Globally, India ranks first in the pigeon pea production with 4.14 million tonnes from 4.71 million hectares and productivity of 877 kg/ha (Government of India 2021). More than 80% area under pulses production is under rainfed and traditional cultivation on marginal and sub-marginal lands, resulting in low productivity and high instability in pulse production (Dass and Sudhishri 2010, Ahlawat et al 2016). However, similar to other crops, the production of pigeon peas is often constrained by a number of biotic and abiotic elements, such as weed competition, moisture stress, nutrient deficiencies, and microbial parameters. Therefore, it is essential to exercise control over these aspects to increase pigeonpea productivity and sustainability (Garud et al 2018). Though pigeon pea is a deep-rooted crop, which is well known for drought tolerance under rainfed upland ecosystem, prolonged dry spells during early growth and flowering to pod formation stages severely affects crop growth and yield (Sangma 2020). Moreover, heavy weed infestation also elevates extreme moisture stress and nutrient deficiencies through increased crop weed competition. Due to severe weed competition; the yield of pigeon pea is reduced by 31.0-52.8% (Chaudhary and Dhakal 2023). Despite the yield loss, weeds infestation causes a decline in the inputs-use efficiency of fertilizers and water, ultimately increases the cost of cultivation (Kumar et al 2023). Thus, it is important to devise suitable management options to mitigate weeds problem, moisture and nutrient stress. Change in the current land configuration might be one of the best ways to conserve and enhance moisture availability to the crop plants throughout the growing season (Garud et al 2019). However, in-situ moisture conservation practices provide the moisture all over the growth stages of the crops and moreover improve physico-chemical and biological properties of the soil (Ngangom et al 2020). In addition, it improves aeration in the rhizosphere which results in enhanced root growth, nodulation, and N-fixation by the Rhizobium bacteria (Sun et al 2022). Augmentation of these practices with efficient weed management options may significantly improve the crop performance which results in higher qualitative crop yields. Manual and mechanical weed management techniques are extremely successful, but they are also costly, tiresome, and time-consuming (Ram et al 2011 and Pratap et al 2023). For effective control of the weeds in the pigeonpea crop, the use of pre-and post-emergence herbicides, such as pendimethalin, imazethapyr, and quizalofop-ethyl has been recommended (Deore 2008 , Reddy et al 2016). Chemical weed management methods are more convenient, less time demanding, and less expensive, and they may offer weed-free conditions from crop plant establishment (Pratap et al 2021a, 23). Hence, the present field experiment was conducted to study the effect of land configuration and weed management options on soil fertility and nutrient uptake by pigeonpea.

MATERIAL AND METHODS

The field experiment was laid-out during *kharif* season in 2020 at the Research Farm of Indian Agricultural Research Institute, New Delhi (28.38° N, 77.18° E and 228.6m elevation). The region has a sub-tropical and semi-arid climate with a mean rainfall 650 mm, hot dry summer (March-June), wet monsoon season (July-September) and a cool winter (October-February). The soil of the experimental site was sandy loam in texture with pH 7.79, low in organic carbon 0.41%, low in available N (196 kg/ha), medium in Olsen P (13.70 kg/ha) and medium in NH_4OAc extractable K (290 kg/ha). The experiment was laid-out in a split-plot design with three land configurations *viz.* Broad bed furrow (BBF), Ridge and furrow (RF), and Flat-bed sowing (BF), in main plot and weed management practices, Weedy check (WM_1), Hand weeding twice at 30 and 60 DAS (WM_2), Metribuzin 0.25 kg/ha (Pre-em.) *fb*. [Imazethypr+Imazamox (premix)] 75 g/ha at 30 DAS (WM_3), Pretilachlor 1.0 kg/ha (Pre-em.) *fb*. [Imazethypr+Imazamox (premix)] 75 g/ha at 30 DAS (WM_4), Metribuzin 0.25 kg/ha (Pre-em.) *fb*. One manual weeding 30 DAS (WM_5), Pretilachlor 1.0 kg/ha (Pre-em.) *fb*. One manual weeding 30 DAS (WM_6) in sub-plots.

Pigeonpea variety 'Pusa Arhar-16; was sown on 27th June 2020 using a seed rate of 15 kg/ha at 45 cm row-to-row and 15 cm plant-to-plant spacing. Crop was applied with FYM @ 5t/ha and fertilized with basal dose of 30 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha through urea, single super phosphate and muriate of potash. Three irrigations were given as and when required to the crop to maintain adequate soil moisture throughout crop growth. Plant samples of crop (seed and stalk) collected at the time of harvest, were dried, processed and analyzed for analyzed for N by micro-Kjeldahl method (Jackson 1973) and N uptake was calculated by multiplying dry matter with N content (%) of plant. The P and K in plant samples were analyzed after digestion with di-acid (HNO_3: $HClO_4$ in the ratio of 10:4) by vanadomolybdo phosphoric yellow colour method and flame photometer, respectively. Soil samples (0-15 cm depth) were collected from each plot with the help of augur after crop harvest and analyzed using standard procedure (Jackson 1973). Data were suitably analysed with using SAS software of ICAR-Indian Agricultural Statistics Research Institute and evaluation was made at 5% level of significance.

Protein yield: Protein yield in seed was calculated by multiplying their respective N content with 6.25. Nutrient uptake (N, P and K) and protein yield was calculated as:

Nutrient uptake(kg/ha) = {Nutrient concentration (%) x Dry weight of stalk (kg/ha)/100}

$$\text{Protein yield (kg/ha)} = \frac{\text{Protein (\%)} \times \text{Seed yield (kg/ha)}}{100}$$

Microbial biomass carbon: The soil samples were estimated by the following protocols given by Nunan et al (1998). The soil microbial biomass carbon (MBC) was then calculated using the following formula:

$$\text{MBC (µg/g of soil)} = \frac{\text{(O.D. of fumigated soil – O.D. of non fumigated soil)}}{\text{Amount of soil used}} \times 15487$$

Dehydrogenase activity: Dehydrogenase activity was determined by measuring the rate of production of tri-phenyl formazan (TPF) from tri-phenyl tetrazolium chloride (TTC), which acts as an electron acceptor. The method used for the assay of dehydrogenase activity followed the procedure outlined by Klein et al (1971).

Alkaline phosphatase activity: Alkaline phosphatase activity in the soil was estimated as described by Tabatabai and Bremner (1969), the values are expressed in terms of µg of p-nitrophenol per gram of soil per hour (µg PNP/gsoil/hr).

Fluorescein diacetate hydrolytic activity: The fluorescein diacetate hydrolytic activity in the soil was measured following the procedure described by Green et al (2006), with values expressed in terms of µg of fluorescein per gram of soil per hour (µg FL/g soil/hr).

RESULTS AND DISCUSSION

N, P and K content in seed and stalk: The N, P and K contents in pigeonpea seeds and stalks were significantly influenced by land configuration and weed management (Table 1). Broad bed and furrow resulted in significantly higher N, P and K content in seed and stalk of pigeonpea over ridge and furrow and flatbed planting system. The nutrient content increased because of the availability of higher soil moisture, aeration, root growth and optimum nutrients availability under broad bed and furrow, and ridge and furrow practice compared to conventional practice (flatbed). Earlier researcher also reported similar findings (Sharma et al 2018, Babu et al 2020 and Rao et al 2022). It is apparent that in weed management options, N, P and K contents in seed as well as in stalk were highest with twice hand weedings at 30 and 60 DAS (WM_2) and found superior over rest of treatment except that the phosphorus content (in seed and stalk) and potassium content in seed was statistically on par with metribuzin+hand weeding at 30 DAS (WM_5), and pretilachlor+ hand weeding at 30 DAS (WM_6). Further, higher content of N, P and K with twice hand weeding and other weed management attributed to the fact that these treatments controlled and checked the weed growth more efficiently and provided favourable environment to the crop for longer time to use moisture and available nutrients resulting in increase of N, P and K content. Komal and Yadav (2015) and Lal et al (2017) observed that maximum nutrient uptake (N, P and K) was in crop grown under broad bed and furrow, and ridge and furrow planting methods.

Protein content and protein yield: Broad bed furrow recorded significantly higher content and yield of protein in seed over FB and RF. However, protein content was statistically at par with RF (Table 1). As protein content is directly related with N content in seed and stalk, the higher protein content in BBF could be due to higher N content in seed than the other treatments. Lower protein content and yield seed was recorded in FB treatments. These findings are in agreed with those reported by Shinde (2012) and Joshi et al (2018). Amongst weed management options, as comparison to the weedy check, all weed managing techniques reported significantly greater protein content in seed. However, WM_2 recorded significantly higher seed protein content being statistically on par with WM_5 and WM_6 treatment, while maximum protein yield was obtained with WM_2 treatment which was greater over rest of treatment. This might be due to higher N content in seed, efficient weed control enabled crop higher uptake of nutrients, as a result higher seed yield and protein yield. The similar results were reported by Kohli et al (2006) and Pratap et al (2021b) that the high protein content and protein yield were mainly due to better control of weeds from the early stages of crop growth due to two hand weeding and pre-emergence application of herbicide and subsequent hand weeding or subsequent herbicide application at later stage of crop growth.

Seed and stalk yield: The maximum seed yield (1.71 t/ha) and stalk yield (4.83 t/ha) were recorded in broad bed and furrow (BBF) and found superior over the RF and FB land configuration (Fig. 1). The yield increased because of increased plant height, number of leaves, number of branches, number of pods/plant and 1000 seed weight, this might be due to the cumulative action of soil moisture, aeration and nutrients in optimum quantity under broad bed and furrow, and ridge and furrow practice compared to conventional practice (flatbed). Similar findings reported by Kantwa et al (2006), Patil et al (2016) and Rao et al (2022). Among the weed management options, the maximum seed yield (1.80 t/ha) and stalk yield (5.19 t/ha) were recorded with WM_2 (Twice hand weeding at 30 and 60 DAS) and found superior over rest of the weed management options except WM_5. Both WM_1 and WM_5 (Metribuzin + hand weeding at 30 DAS) were statistically at par with respect to both seed and stalk yield. The stalk yield was statistically at par among WM_1, WM_5 and WM_6. The minimum seeds yield was achieved in weedy check due to severe-weed competition faced by the crop. Similar results were reported by Choudhary et al (2012), Bhowmick et al (2015) and Yadav et al (2015).

N, P and K uptake by seed and stalk: The BBF showed significantly higher N, P and K uptake by seed and stalk over RF and FB, which could be attributed to higher seed and stalk yield as a result of better growing condition during crop growth period which aids in greater absorption and translocation of nutrients in different plant parts as a result of greater weed control. Jat et al (2012) and Patel et al (2013) also reported similar findings, where minimum N, P and K uptake was found under FB because of lower seed and stalk yield due to more density and dry weight of weeds results in more nutrient depletion by the weeds. Twice hand weedings at 30 and 60 DAS (WM_2) recorded higher N, P and K uptake by seed and stalk over rest of the treatments, whereas weedy check plot recorded lowest uptake of nutrient (N, P and K) (Table 2). This might be due to lower depletion of soil nutrient by the weeds due to efficient control of all weeds under two

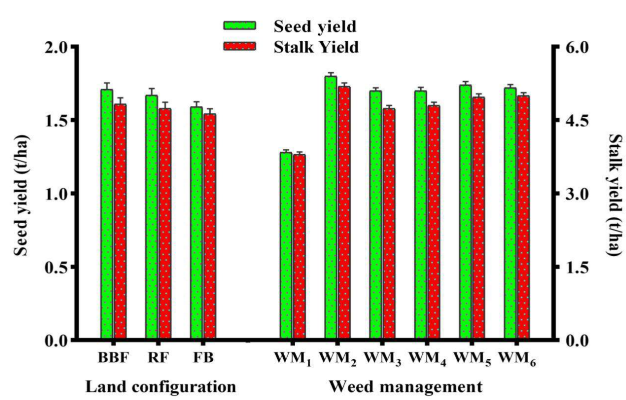

Fig. 1. Effect of land configuration and weed management practices on seed and stalk yield of pigeonpea

hand weeding and all other weed management treatments compared to weedy check apart of these leaving larger amount of nutrients for absorption and translocation in different plant parts. Vyas et al (2013), Pratap et al (2021b) and Komal and Yadav (2015) also observed higher weed density and dry matter production in weedy check allowed the weeds to deplete higher amount of nutrients from the soil.

Available N, P, K and organic carbon: Pigeonpea sown on BBF recorded significantly higher available N, P and K in soil over FB and RF except N and P which, being at par with RF. However, no significant effect of land configuration observed on organic carbon (Table 3). This might be attributed by lower depletion of nutrients (N, P and K) by reduced weed infestation by enabling the crop to utilize growth resources more efficiently, as a result of higher weed suppression under broad bed and furrow, and ridge and furrow treatments. Among weed management options all the treatments recorded significantly higher N, P and K over WM_1 (weedy check) and WM_4 except P. However, WM_2 (twice hand weedings at 30 and 60 DAS) recorded maximum recorded higher available N, P and K in

Table 1. Effect of land configuration and weed management on NPK content in seed and stalk of pigeon pea

Treatments	N content (%)		P content (%)		K content (%)		Protein content (%)	Protein yield (kg/ha)
	Seed	Stalk	Seed	Stalk	Seed	Stalk		
Land configuration								
BBF	3.19	1.22	0.36	0.22	1.24	1.83	20.0	342.3
RF	3.12	1.20	0.34	0.20	1.21	1.77	19.7	327.9
FB	3.14	1.20	0.32	0.19	1.20	1.60	19.5	313.1
LSD (p=0.05)	0.04	0.02	0.03	0.02	0.02	0.07	0.3	5.9
Weed management								
WM_1	2.90	1.17	0.30	0.14	1.17	1.58	18.2	232.6
WM_2	3.33	1.24	0.37	0.25	1.24	1.86	20.8	375.8
WM_3	3.14	1.20	0.33	0.20	1.21	1.72	19.6	333.4
WM_4	3.11	1.19	0.32	0.18	1.20	1.68	19.5	329.9
WM_5	3.25	1.22	0.36	0.23	1.23	1.80	20.3	353.0
WM_6	3.18	1.22	0.34	0.21	1.22	1.75	19.9	341.9
LSD (p=0.05)	0.15	0.03	0.03	0.04	0.02	0.05	0.9	16.5

Table 2. Effect of land configuration and weed management on NPK uptake in seed and stalk of pigeonpea

Treatments	N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	Seed	Stalk	Seed	Stalk	Seed	Stalk
Land configuration						
BBF	54.8	60.0	6.1	10.6	21.0	90.4
RF	52.5	57.6	5.7	9.4	20.3	85.3
FB	50.1	54.5	5.1	9.1	19.1	73.4
SEm±	0.2	0.4	0.1	0.2	0.1	0.9
LSD (p=0.05)	0.9	1.5	0.5	0.7	0.2	3.4
Weed management						
WM_1	37.2	43.0	3.9	5.0	15.0	58.2
WM_2	60.1	64.2	6.8	13.1	22.4	96.5
WM_3	53.4	58.4	5.7	10.3	20.6	84.2
WM_4	52.8	57.8	5.5	9.0	20.3	82.3
WM_5	56.5	60.7	6.2	11.3	21.4	90.3
WM_6	54.7	60.1	5.9	9.5	21.0	86.8
SEm±	0.9	0.7	0.2	0.6	0.2	1.2
LSD (p=0.05)	2.6	2.1	0.5	1.8	0.6	3.5

soil which was found at par with WM_3 (metribuzin + imazethapyr), WM_5(metribuzin+ hand weeding at 30 DAS) and WM_6 (pretilachlor + hand weeding at 30 DAS). This might be possible through reducing nutrient removal by weeds because of efficient control of weeds during crop period. These findings are in close with findings of Pratap et al (2021a).

Soil biological properties: Both land configuration and weed management practices influenced biological properties significantly (Table 4). The broad bed and furrow (BBF) recorded significantly higher soil microbial biomass carbon (SMBC), dehydrogenase activity (DHA), alkaline phosphatase activity (ALP) and fluorescein diacete hydrolysis (FDA) over FB treatment. However, DHA, ALP and FDA were at par with RF treatment except SMBC. The flatbed sowing has lowest soil biological activity. It could be due to FYM application, leaf drop, low C:N ratio and legume effect in tillage practices which might have led to higher microbial and enzymatic activities. The similar result reported by Tao et al (2009), Dodor and Tabatabai (2003), Perez-Brandan et al (2012) and Gajda et al (2013). Among weed management options significantly higher SMBC, DHA and ALP were in WM_2 which were at par with WM_5 except SMBC which was also at par with WM_3 and WM_6. However, FDA activity significantly higher in WM_2 over rest of other treatments. The

Table 3. Effect of land configuration and weed management on available NPK and organic carbon in soil after harvest of crop

Treatments	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Organic carbon (%)
Land configuration				
BBF	218.9	16.8	263.9	0.42
RF	210.5	16.0	249.5	0.42
FB	200.0	15.2	237.0	0.41
SEm±	2.6	0.2	2.7	0.02
LSD (P=0.05)	10.3	0.8	10.8	NS
Weed management				
WM_1	178.1	14.1	220.4	0.41
WM_2	227.5	17.0	268.6	0.42
WM_3	214.9	16.4	252.3	0.41
WM_4	206.3	15.7	247.7	0.42
WM_5	220.5	16.8	260.1	0.42
WM_6	211.4	16.1	251.5	0.42
LSD (P=0.05)	18.3	1.5	18.7	NS

Table 4. Effect of land configuration and weed management on the soil microbiological properties of soil after the harvest of pigeon pea crop

Treatments	SMBC (µg C/g soil)	DHA (µg TPF/ g soil/24 hr)	ALP (µg p-NP/g /hr)	FDA (µg FL/ g soil/hr)
Land configuration				
BBF	253.3	225.8	285.8	0.61
RF	214.5	216.0	274.2	0.59
FB	191.3	197.5	252.5	0.47
LSD(P=0.05)	33.1	14.5	16.0	0.03
Weed management				
WM_1	187.3	176.7	228.3	0.46
WM_2	241.6	235.8	294.1	0.68
WM_3	217.4	213.1	274.0	0.53
WM_4	207.7	209.7	265.8	0.50
WM_5	235.6	225.9	288.8	0.61
WM_6	228.5	217.4	273.8	0.57
LSD (P=0.05)	29.9	11.7	13.9	0.02

least biological activity was with weedy check (WM_1). The effects of stimulation or inhibition of the above activity because of application of various pesticides have been reported in numerous studies (Das and Varma, 2011, Jinger et al 2016, Lal et al 2017 and Rasool et al 2014).

CONCLUSION

Thet broad bed and furrow practice improve OC, available N, P, K and soil biological properties in soil as well as total N, P, K and protein content, protein yield and uptake by the crop which significantly superior over ridge and furrow and flatbed method. The twice hand weeding given at 30 and 60 days after sowing proved superiority in terms of OC, available N, P, K and soil biological properties in soil as well as N, P, K and protein content, protein yield and uptake by the crop.

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Received 17 December, 2023; Accepted 19 April, 2024