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FULL-LENGTH RESEARCH ARTICLE

Impact of Establishment Techniques and Maturity Duration of Pigeon Pea Cultivars on Yield, Water Productivity and Properties of Soil

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Abstract India is the leading country with respect to area and production of pulse crop pigeon pea (*Cajanus cajan* L.). However, the productivity of this crop is too low and almost static for the last five decades due to cultivation of long-duration cultivars that are prone to climatic variations causing temporary water logging, drought and frost. Proper selection of the cultivar and use of appropriate crop establishment may help in enhancing productivity. Therefore, a field investigation was carried out for 3 consecutive years to determine the impact of establishment techniques on cultivars of two maturity durations—long (250–280 days; cv. JA-4) and short (130–145 days; cv. ICPL-88039), grown using the conventional tillage (CT), minimum tillage (MT), zero tillage (ZT) and broad bed furrow (BBF). The BBF method significantly improved the growth, biological yield, harvest index ratio, water productivity and physicochemical properties compared to the CT, MT and ZT. The yield of pigeon pea seed and stalk under the BBF increased 9.9 and 4.1% compared to the CT. The short-duration cultivar produced higher yield (16.8%) in frost-affected year (2012–2013) but was at par with the long-duration cultivar during the normal climatic condition year (2013–2015). Overall, the short-duration cultivar produced significantly higher yield. Land use efficiency and total water use were significantly higher for the long-duration cultivar a compared to the short-duration cultivar, whereas production efficiency and water productivity were higher for the short-duration cultivar. Compared to the other tillage practices, BBF showed significantly higher organic carbon and infiltration rate but decreased pH. The trend of infiltration rate was in the order BBF > ZT > MT > CT. The bulk density of surface (0–15 cm) and sub-surface (15–30 cm) layers were significantly lower under the BBF compared to the other tillage practices. Maximum increment of available N, P, K and S in surface soil (0–15 cm) was recorded under the BBF. For the short-duration maturity cultivar of pigeon pea the BBF method appeared beneficial in terms of assured higher yield, improved water productivity and physicochemical properties of soil under variable climatic conditions in Central India.

Keywords Tillage · Pigeon pea · Yield · Water productivity · Physicochemical properties · Climatic conditions · Broad bed furrow · Biological yield · Harvest index

Introduction

Pigeon pea (*Cajanus cajan* (L.) Millsp.) is a major seed legume (pulse) grown in about 50 countries in the tropics and subtropics and accounts for ∼ 5% of global pulse production. In Asia, it is grown in 4.33 m ha with a production of 3.8 m t. India has the largest area (3.38 m ha) followed by Myanmar, China and Nepal [21]. The Indian subcontinent alone contributes nearly 92% of the total

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pigeon pea production of the world. Although India leads the world both in area and production, productivity remained almost static during last 50 years [23]. In 2013–2014, productivity was around 25% lower (730 kg ha^{-1}) than the world average (910 kg ha^{-1}). Pigeon pea is known to provide several benefits to the soil as soil ameliorant. For instance, it is known that it adds 40–50 kg N ha^{-1} to the soil through biological nitrogen fixation and leaf fall [1].

It has been observed that the long-duration pigeon pea cultivars (250–280 days) that occupy fields for nearly whole of the year get damaged by the winter frost. On the other hand, short-duration cultivars have been found to fit well in various multiple cropping systems under irrigated or rainfed conditions. These short-duration high yielding cultivars enable a second crop which can be wheat, barley, mustard or chickpea in the *rabi* season. Short-duration cultivars mature in about 130–145 days and can escape the risk of frost [17].

Pigeon pea crop is planted after 5–7 tillage operations in rainy (*kharif*) season in North, Western and Central India. Sowing is done in flat bed which is prone to water logging resulting in plant mortality and higher incidence of *fusarium* wilt and *phytopthora* blight [27]. Land preparation requires high input of energy and results in loss of soil moisture due to a number of ploughings and increased cost of cultivation. Further, this also delays sowing that leads to late sowing of winter crops such as wheat and barley. Resource conservation agriculture (RCT) practices such as zero tillage (ZT) and bed planting have been shown to be beneficial in terms of improving physicochemical soil properties, water use, crop productivity, time saving and farmers' income [11, 12]. ZT is widely adopted for sowing of wheat in North-Western Indo-Gangetic Plains IGP, particularly where rice is harvested late. In wheat, ZT has been demonstrated to reduce irrigation requirements compared with CT by using residual water more effectively [5, 10]. It can save 13–33% water use and 75% fuel consumption in wheat [18], whereas bed planting has the potential to save water by 30–50% in wheat [25, 32]. Other benefits include reduced seed rate, rain water conservation, mechanical weeding, less crop lodging and soil erosion [9]. However, the information on comparative performance of long- and short-duration maturity cycle pigeon pea cultivar in response to establishment technique is lacking. In view of above, this study was planned to evaluate the relationships of establishment techniques and maturity cycle of pigeon pea on yield, water productivity and physicochemical properties under sandy loam soils of Central India.

Materials and Methods

Experimental Site

A field experiment was carried out at the research farm of Zonal Agricultural Research Station R.V.S. Krishi Vishwa Vidyalaya (RVSKVV), Morena, Madhya Pradesh (MP), India. The study area lies 26°28′N–latitude and 77°59′E—longitude with an altitude 179 m. The agro-climatic region of MP is Central Plateau and Hills Region. The state is further divided into 11 sub agro-climatic zones, and Morena district falls under Gird agro-climatic zone. The climate of this zone is characterized as semi-arid, extremely cold during December–January (− 1.0 °C minimum temperature) and hot during May–June (49 °C maximum temperature). The major climatic vulnerabilities of the zone are frost, drought and heat. Average annual rainfall of this zone is 701 mm, mostly concentrated in July and August. The temperature and rainfall pattern during study period of experimental farm is given in Fig. 1. The minimum and maximum temperature ranges were 0–47.5, 4–47 and 3–48 °C, while total rainfall received was 1074, 1028 and 482 mm, during 2012–2013, 2013–2014 and 2014–2015, respectively. Maximum quantity of rainfall is received in the months of July and August. Out of experimentation years, minimum temperature 0 °C was recorded on 8th January 2013 and frost infestation was also seen. The soil of the experimental field was alluvial, non-calcareous in nature, and no hard pan exists up to 120 cm depth. The effective soil depth was 150 cm. Permeability and drainage conditions of these soils were moderate. Water table varies from 120 to 140 feet.

Soil Sampling and Analysis

Soil samples were collected from 0 to 15 cm layer before sowing and after harvest of the third crop from three locations within a plot. Freshly collected soil samples were mixed thoroughly, air-dried, crushed to pass through a 2-mm sieve and stored in plastic jars before analysis. Organic carbon was analyzed by Walkley and Black method [30]; available N by Kjeltec-II auto analyzer, P by Olsen method [19], S by Chesnin and Yien method [3], K by NH_4OAc extraction and Zn by DTPA extraction method. Bulk density of soil from 0–15 and 15–30 cm layers was determined by using clod method [2]. Infiltration rate was measured after harvest of crop using a double-ring infiltrometer. The soil of the experimental plot was a sandy loam in texture (*Typic Ustochrept*) with 59% sand, 25% silt and 16% clay, well drained having infiltration rate of 7.3 mm h^{-1}, slightly alkaline in reaction with pH 7.95 and bulk density 1.55 Mg m^{-3}. The soil was low in soluble

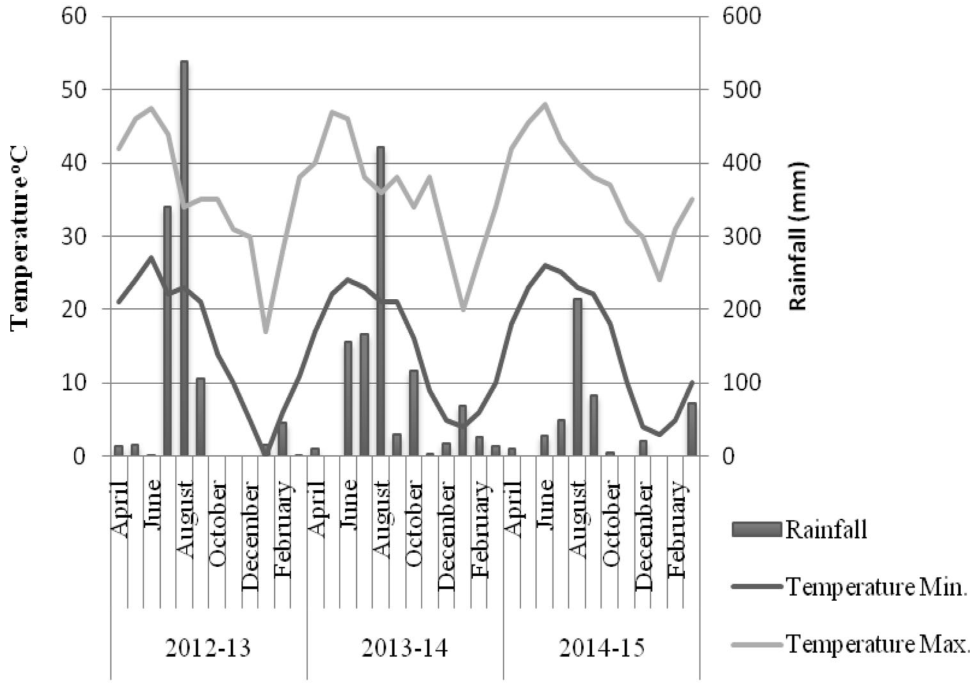

Fig. 1 Monthly total rainfall, minimum and maximum temperature during experimentation period

salts (EC 0.29 dS m^{-1}) and organic carbon (3.4 g kg^{-1}). The other soil characteristics were: deficient in available nitrogen (165 kg ha^{-1}) and sulphur (9.9 kg ha^{-1}), medium in phosphorus (12.6 kg ha^{-1}) and potassium (264 kg ha^{-1}).

Experimental Details

The experiment was conducted for 3 years (2012–2015) in split plot design [20] with 3 replications. Four tillage practices for crop establishment were used as main plot. Tillage practices were: conventional tillage (CT), minimum tillage sowing by seed cum fertilizer drill (MT), zero till sowing by zero till seed cum fertilizer drill (ZT) and sowing by broad raised-bed furrow seed cum fertilizer drill (BBF). Details of various tillage practices followed were—two harrowing followed by two ploughing by cultivator along with plunking and crop sown by single box seed drill for CT; two ploughing by cultivator along with plunking and sowing by seed cum fertilizer drill for MT; direct seeding by zero till seed cum fertilizer drill for ZT and two ploughing by cultivator along with plunking and sowing by broad bed seed cum fertilizer drill for BBF, respectively. The leaf litter and stubbles of previous pigeon pea crop (cutting at 30 cm height at maturity) were retained on the surface in ZT, whereas there were incorporated during tillage in CT, MT and BBF plots. The sowing methods are given in Fig. 2. The long (JA-4)- and short-duration (ICPL-88039) cultivars were sown in subplots (50 m^2). Pigeon pea treated cultivars (2 g *Thiram*, *Rhizobium* and *PSM* @

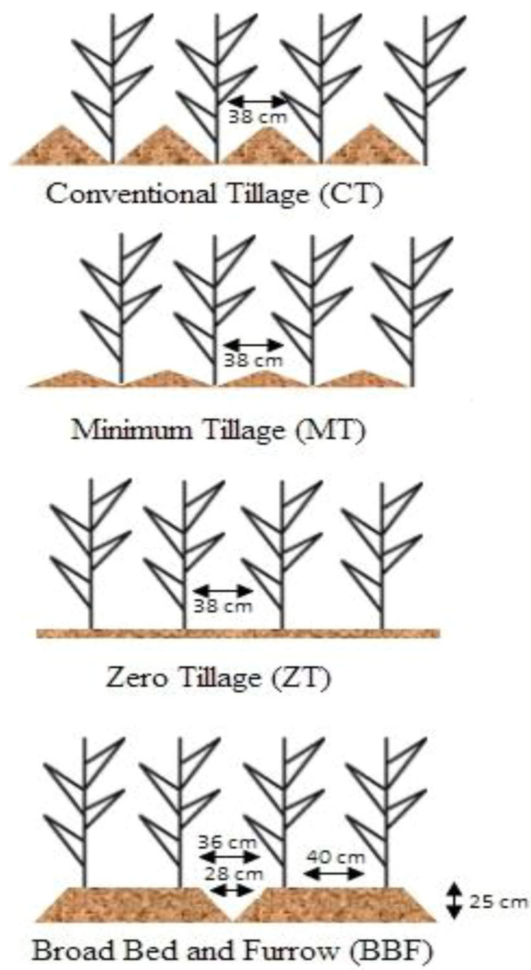

Fig. 2 Schematic diagram of different sowing methods

20 g kg^{-1} seed) was sown @ 18 kg ha^{-1} in fourth week of June in every year after pre-irrigation (7 cm). *Imazethapyr* 10% SL @ 75 g ha^{-1} at 18–20 DAS was applied for control of weeds in all treatments. Full recommended dose of chemical fertilizers (20 kg N, 50 kg P_2O_5, 20 kg K_2O and 30 kg S ha^{-1}) was applied as basal in all treatments. The sources of N, P, K and S were urea, di-ammonium phosphate, muriate of potash and elemental sulphur, respectively. Irrigation was applied once in long-duration cultivar in normal as well as frost infestation year for re-growth, whereas short-duration maturity cultivar was grown as rainfed. One spray of *trizophos* @ 750 ml ha^{-1} was applied for control of pod borer at flowering stage of crop.

Crop Harvesting and Observations

Short-duration cultivar was harvested in third week of November, while long-duration cultivar in the fourth week of March during all the years. At the time of maturity of pigeon pea, growth characters of 20 randomly selected plants from each treatment and replication were recorded. After harvest, seed and stalk yields and 1000-seed weight (oven dried at 70 °C) were recorded. Harvest index was calculated by = Seed yield/Seed + stalk yield. The land use and production efficiency were calculated as: Land use efficiency (%) = Total duration of crop/365 × 100, and production efficiency (kg ha^{-1} day^{-1}) = Total seed production ha^{-1}/Total duration of crop.

Water Management Studies

Irrigation water and surface run-off were measured using a Parshall Flume having 15-cm throat width. Soil water content of soil profile (0–150 cm) was measured gravimetrically, at 15 cm increment of first two layers and 30 cm increment subsequently. Soil moisture (%) was determined thermo-gravimetrically. The total water used was estimated by the water balance equation: Total water use (ET) = S + I + P + C − D − R.

In which S = change in soil moisture in root zone; I = irrigation water applied; P = effective rainfall; C = ground water contribution; D = downward movement from crop root zone; and R = surface water run-off.

Change in soil moisture in root zone was determined by sampling at successive intervals. During cropping period of long- and short-maturity duration cultivar of pigeon pea, the rainfall received was 989 and 945, 849 and 736 and 388 and 367 mm, during 2012–2013, 2013–2014 and 2014–2015, respectively. The surface run-off was 199 mm, 50 mm during only 2012–2013 and 2013–2014. The contribution from ground water and downward drainage was nil because of good distribution of rainfall, i.e. higher (33–62) number of rainy days. Irrigation water productivity was calculated as: Water productivity (kg seed m^{-3})-= Seed yield of pigeon pea (kg ha^{-1})/Total water use (m^{-3} ha^{-1}).

Results and Discussion

Growth Characters

Sowing by BBF significantly increased growth characters as compared to other tillage practices like CT, MT and ZT (Table 1). The high intensity rains (113.6 mm) received during July 2012 caused high plant mortality in the flat bed (CT, MT and ZT) sown crop as the plants were in the initial stage (16 days old). The average plant mortality under CT, MT and ZT was 21–23%, but only 3% in BBF. The increase in plant height, primary and secondary branches, number of pods $plant^{-1}$ and length of pods under BBF was 7.9, 9.4, 6.5, 8.0 and 4.6% as compared to CT. Maximum values of growth under BBF appeared to be due to constant higher moisture availability and additional surface area for transpiration compared to CT. Minimum values were recorded under CT. This could be due to depletion of oxygen in the root zone caused by water stagnation which also reduced root growth by inhibiting aerobic respiration [14], and the process of nodulation and N fixation [29]. Non-significant differences in growth characters were observed among CT, MT and ZT treatments.

Plant height, primary and secondary branches, number and length of pods and days of maturity varied significantly with different maturity duration of cultivars (Table 1). The plant height of long-duration maturity cultivar was significantly higher (190.8 cm) compared to short-duration maturity cultivar (183.1 cm). While number of primary branches (15.2), number of secondary branches (11.0), pods per plant (187.0), pod length (46.3 mm) and number of seeds per pod (4.1) were higher in short-duration cultivars compared to long-duration. Around one-fifth (22.1%) plants of the long-duration cultivar were affected by frost attack on 8th January 2013.

Seed Yield and Its Attributes

The BBF method significantly influenced 1000-seed weight, seed, stalk, biological yield and harvest index as compared to MT, ZT and CT, whereas these values were at par for CT, MT and ZT (Table 2). The increase in seed and stalk yields was 9.9 and 4.1% by BBF compared to CT. It was reported that the wheat yield at farmers fields of Mexico achieved 10% higher yield by adopting furrow-irrigated raised-bed system [24]. Similarly, under Indian conditions, planting of *kharif* pulses viz. cluster bean and

Table 1 Impact of tillage and maturity duration of pigeon pea cultivars on growth parameters (pooled data of 3 years)

Treatments	Plant mortality (%)[a]	Plant height (cm)	Primary branches (no)	Secondary branches (no)	Pods plant^{-1}	Pod length (mm)	Seed pod^{-1}	Days of maturity (no)	Frost affected plant (%)[b]
Tillage methods									
CT	21	182.8	13.9	10.8	181.1	43.7	4.18	187	23.5
MT	23	183.9	13.8	10.7	182.2	43.5	4.15	186	21.8
ZT	21	183.2	14.0	10.8	181.5	43.9	4.16	186	20.4
BBF	03	197.2	15.2	11.5	195.5	45.7	4.24	188	22.7
CD at 5%	06	3.80	0.47	0.26	4.81	0.73	0.03	0.67	–
Maturity duration of cultivar									
Short	18	183.1	15.2	11.0	187.0	46.3	4.11	143	–
Long	16	190.8	13.3	10.9	183.1	42.0	4.01	230	22.1
CD at 5%	NS	5.83	NS	NS	NS	1.21	0.05	1.03	–

CT conventional tillage, *MT* minimum tillage, *ZT* zero tillage, *BBF* broad bed furrow

[a]Mortality of plant during second week of July 2012

[b]Long-duration maturity cycle cultivar affected by frost at 8th January 2013

Table 2 Impact of tillage and maturity duration of pigeon pea cultivars on yield and yield attributes (pooled data of 3 years)

Treatments	1000 seed weight (g)	Seed yield (q ha^{-1})				Stalk yield (q ha^{-1})	Biological yield (q ha^{-1})	Seed harvest index	Land use efficiency (%)	Production efficiency (kg ha^{-1} day^{-1})
		2012–2013	2013–2014	2014–2015	Pooled					
Tillage methods										
CT	94.08	22.75	24.19	22.45	23.13	80.09	103.22	0.22	44.0	14.4
MT	94.26	23.07	23.95	22.70	23.24	79.24	102.48	0.23	43.9	14.4
ZT	94.35	22.90	23.83	22.54	23.09	79.49	102.58	0.23	43.9	14.5
BBF	96.04	24.48	26.03	25.78	25.43	83.06	108.49	0.24	44.6	15.6
CD at 5%	0.65	0.58	0.73	1.11	0.60	1.27	2.12	0.007	0.19	0.09
Maturity duration of cultivar										
Short	101.48	23.31	25.89	23.40	24.20	83.55	107.75	0.22	39.1	17.0
Long	87.89	19.95[a]	26.32	23.78	23.35	71.89	95.24	0.25	51.1	12.5
CD at 5%	1.02	0.89	NS	NS	0.84	2.01	3.23	0.012	0.29	0.14

CT conventional tillage, *MT* minimum tillage, *ZT* zero tillage, *BBF* broad bed furrow, *B:C* benefit–cost ratio

[a]Crop affected by frost

green gram on furrow-irrigated raised-bed system increased crop yield by 8–22%, gave higher monetary benefit and saved 25% of irrigation water over flat-sown system [4].

Long-duration maturity cultivars of pigeon pea are known to suffer from frost in North-Western and Central India. On the other hand, the short-duration cultivars mature before the probable time of frost which generally falls between the ends of December to whole of January. This was apparent in 2012–2013 cycle when the heavy frost led to yield reduction of 16.8% in the long-duration cultivar compared to short-duration cultivar. During the year of frost, minimum temperature goes up to 0 °C, 1 mm potential evaporation and wind speed 1.3 km h^{-1} on 8th January 2013. The 3-year average seed and stalk yield was 3.6 and 16.2% higher in short-duration cultivar. In addition, the short-duration cultivar had significantly higher 1000-seed weight (Table 2). However, harvest index was higher in long-duration cultivar. The short-duration cultivar gave additional 0.85 q ha^{-1} seed and 11.66 q ha^{-1} stalk yield of pigeon pea compared with long-duration cultivar (23.35 q ha^{-1} seed and 71.89 q ha^{-1} stalk). In addition to higher yield, the short-duration cultivars have additional advantage of early vacation of field which unlike long-duration cultivars, do not delay the sowing of succeeding crop. Overall, short-duration cultivars are better equipped to reduce the risk of climatic change [22].

Land Use and Production Efficiency

Land use and production efficiency were significantly greater under BBF (Table 2). Maximum production efficiency (15.6 kg ha^{-1} day^{-1}) was observed under BBF, while minimum (14.4 kg ha^{-1} day^{-1}) under CT. This proves again that BBF method was better compared to other tillage methods.

The value of land use and production efficiency significantly differed between short- and long-duration cultivars. Land use efficiency was higher (51.1%) in long-duration cultivar than short duration (39.1%). However, production efficiency in kg ha^{-1} day^{-1} was much higher (17.0) in short-duration cultivar compared to long-duration (12.5).

Water Productivity

Total water use by pigeon pea varied from 484 to 862 mm ha^{-1} (Fig. 3) under different tillage, but it was significantly higher in CT (548–856 mm ha^{-1}) than ZT (532–838 mm ha^{-1}) and BBF (484–796 mm ha^{-1}). Variations occurred in total water use due to variability of rainfall in respective years. Total water use was statistically at par under CT and MT. Overall irrigation water saving was 9.5% in BBF as compared to CT. Less saving of water in *kharif* by BBF compared with *rabi* season due to rainy season crop. Over all total water use by flat-sown method was significantly higher from BBF rather than CT, MT and ZT treatment. In Mexico, reduction in irrigation water requirement up to 35% under BBF has been reported at farmer field [25]. Likewise, sowing of wheat crop by BBF was able to save 36% irrigation water in North-West India [32]. Therefore, water-use efficiency is significantly higher under BBF as compared to other methods. In all 3 year of experimentation, it was 0.266–0.308 kg seed m^{-3} during 2012–2013, while 0.409–0.533 kg seed m^{-3} during 2014–2015 (Fig. 4). Pooled maximum water productivity was 0.378 kg seed m^{-3} water in BBF followed by ZT (0.322 kg seed m^{-3} water), MT (0.313 kg seed m^{-3} water) and CT (0.312 kg seed m^{-3} water). The higher water productivity in BBF could be attributed to higher yield with lower amount of irrigation water use. Similarly, higher water-use efficiency in rainy season pulse crops was reported through ridge furrow method [4]. The ZT sowing also improved water-use efficiency of wheat [9] and pigeon pea as compared to conventional tillage [28].

Total water use was significantly higher for long-duration compared to short-duration cultivar (Fig. 3). Pooled total water use was significantly higher for long-duration cultivar (753 mm ha^{-1}) than that for shorter-duration (686 mm ha^{-1}). Accordingly, water productivity was significantly higher in short-duration cultivar (0.353 kg seed m^{-3} water) than in long-duration (0.310 kg seed m^{-3} water). The water productivity was

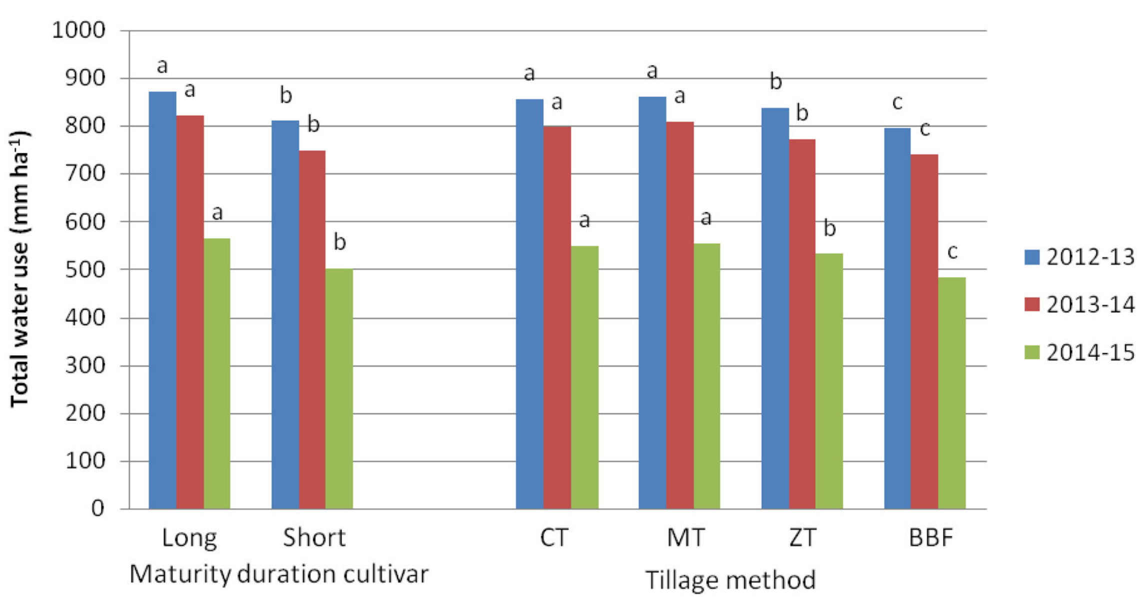

Fig. 3 Impact of tillage and maturity duration of pigeon pea cultivars on total water use. Bars followed by a similar letter of columns are not significantly different statistically at CD 5%

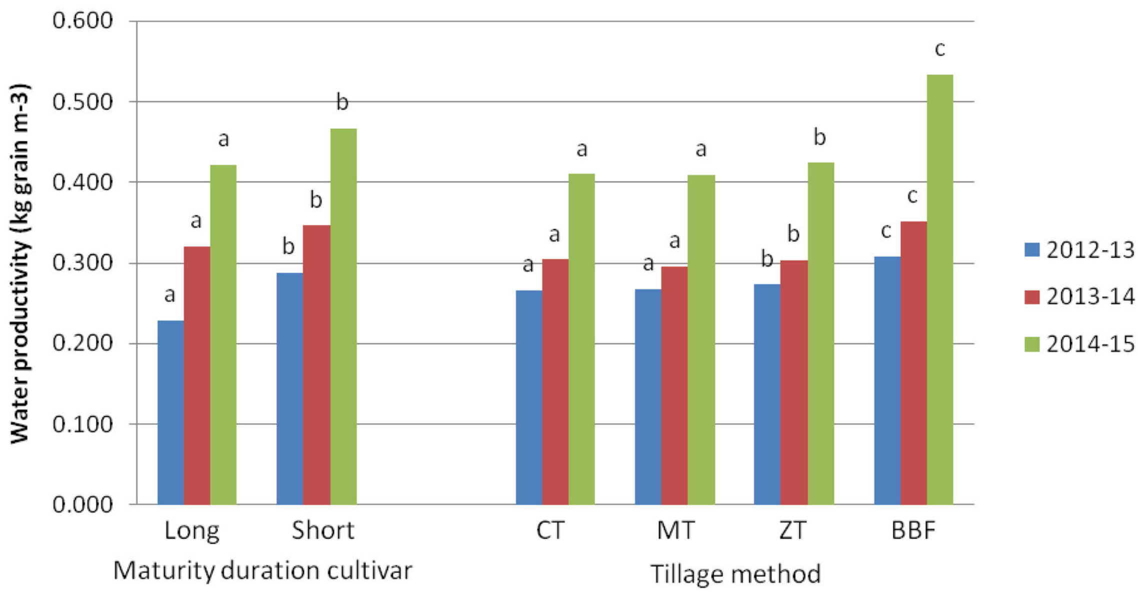

Fig. 4 Impact of tillage and maturity duration of pigeon pea cultivars on water productivity. Bars followed by a similar letter of columns are not significantly different statistically at CD 5%

higher ($0.421 \text{ kg seed m}^{-3}$) in lower rainfall year (2014–2015) and lower ($0.229 \text{ kg seed m}^{-3}$) in higher rainfall year (2012–2013) of long-duration cultivar (Fig. 4). Like-wise similar trend was also observed for short-duration cultivar.

Physicochemical Properties of Soil

Compared to CT, MT and ZT, planting under BBF appeared to improve physicochemical properties of soil as it lowered pH, while there was significant increase in the infiltration rate, organic carbon, available N, P and K (Table 3). The decrease in pH was highest (− 0.21) under BBF followed by ZT (− 0.13), MT (− 0.11) and CT (− 0.10) from the initial pH of 7.80. Maximum addition of organic carbon ($+ 1.45 \text{ g kg}^{-1}$) was obtained under BBF followed by ZT ($+ 0.80 \text{ g kg}^{-1}$), MT ($+ 0.71 \text{ g kg}^{-1}$) and CT ($+ 0.48 \text{ g kg}^{-1}$) to the initial value of organic carbon 3.40 g kg^{-1}. The higher SOC contents in bed sowing compared to flat might be due to more root proliferation and leaf biomass of pigeon pea [13, 23]. Another study showed that raised-bed planting helps to improve soil organic matter and physical characteristics owing to surface retention of residues [8]. The bulk density of surface (0–15 cm) and sub-surface soil (15–30 cm) was significantly lower under BBF than other treatments. Lowest bulk density was noticed in surface soil (0–15 cm depth), possibly due to decomposition of crop residues and higher root mass in surface soil, while there was slight increase in the bulk density of sub-surface soil (15–30 cm depth) in other treatments. Improved soil physical health under raised-bed sowing could be due to reduced disruption of aggregates and settlement under unsaturated conditions compared to the saturated conditions of the flat sowing [6, 13]. Other studies [7, 31] have also reported that longer-duration tillage increases oxidation of organic matter resulting in higher bulk density.

The maximum addition of available N was 72.5 kg ha^{-1} under BBF, followed by ZT (66.8 kg ha^{-1}), MT (61.3 kg ha^{-1}) and CT (59.7 kg ha^{-1}) to the initial value of $152.0 \text{ kg N ha}^{-1}$ after the harvest of third crop of pigeon pea (Table 3). This is perhaps due to more favourable effect of BBF on root and nodules development. Similarly, maximum addition of available P was 7.19 kg ha^{-1} under BBF followed by ZT (5.74 kg ha^{-1}), MT (5.15 kg ha^{-1}) and CT (3.58 kg ha^{-1}) to the initial value of 12.6 kg ha^{-1}. Likewise, increase in available K was 28.4 kg ha^{-1} under BBF followed by ZT (25.9 kg ha^{-1}), MT (22.3) and CT (20.8 kg ha^{-1}) above the initial value of 264.0 kg ha^{-1}, and additions of available S were 5.85 kg ha^{-1}under BBF followed by ZT (4.83 kg ha^{-1}), MT (2.84) and CT (1.83 kg ha^{-1}) above the initial value of 9.90 kg ha^{-1}. Studies show that in the longer term, recycling of more crop residues and roots in beds can contribute significantly to the build-up of soil organic matter and availability of nutrients [15], whereas continuous tillage degrades soil organic matter which reduces soil fertility as well as structural stability [16, 26].

The variable maturity duration of pigeon pea cultivar did not significantly influence the pH, EC, infiltration rate, bulk density and available Zn in soil (Table 3). On the other hand, organic carbon, available N, P and K were

Table 3 Impact of tillage and maturity duration of pigeon pea cultivars on physicochemical properties of soil after harvest of third crop

Treatments	pH	EC (dS m^{-1})	OC (g kg^{-1})	I R (mm h^{-1})	Bulk density (Mg m^{-3})		Available nutrients (kg ha^{-1})			
					0–15 (cm)	15–30 (cm)	N	P	K	S
Tillage methods										
CT	7.70	0.31	3.88	7.9	1.53	1.59	211.7	16.18	284.8	10.73
MT	7.69	0.33	4.11	8.0	1.52	1.57	213.3	17.75	286.3	11.74
ZT	7.67	0.31	4.20	9.1	1.48	1.53	218.8	18.34	289.9	13.73
BBF	7.59	0.30	4.58	9.5[a]	1.46	1.49	224.5	19.79	292.4	15.75
CD at 5%	0.04	NS	0.04	0.1	0.02	0.02	4.11	0.08	1.45	0.02
Maturity duration of cultivar										
Short	7.69	0.32	4.21	8.7	1.49	1.54	213.1	18.08	292.2	13.96
Long	7.71	0.33	4.17	8.6	1.51	1.55	221.4	17.95	284.6	12.02
CD at 5%	NS	NS	NS	NS	NS	NS	6.17	0.13	2.20	NS
Initial value	7.80	0.29	3.40	7.3	1.55	1.57	152.0	12.6	264.0	9.90

CT conventional tillage, *MT* minimum tillage, *ZT* zero tillage, *BBF* broad bed furrow, *EC* electrical conductivity, *OC* organic carbon, *IR* infiltration rate

[a]On the bed

significantly affected. Shorter-duration cultivar showed higher organic carbon content and available P, whereas longer-duration cultivar showed higher available N and K after harvest. Increase in available nutrients could be due to the fact that pigeon pea crop was capable of exploiting nutrients from deeper layers of soil through its deep and extensive rooting system. Variations in the addition of organic carbon, available N, P and K were due to recycling of variable amounts of root, stubbles and leaf litter under the two different maturity durations of pigeon pea cultivars.

Conclusions

The area of long-duration cultivars of pigeon pea in Central India is shrinking as the crop has been found to suffer from severe frost and that there is scope of only a single crop in a year. Indian farmers from ancient times had an opinion that for getting higher yields of crops, fine seedbed was necessary. Accordingly, pigeon pea has been sown following 5–7 tillage operations. Recently this involved heavy machinery which resulted in the compaction of sub-surface soil. On the other hand, pigeon pea with its tap root system was known to break the plough pans and was rightly called the “biological plough”. In this study, short-duration cultivars (ICPL-88039) gave significantly higher seed yield, using lesser water and increasing organic carbon content in soil. The short-duration cultivar was also increasing production efficiency. The technology of BBF sowing was found to be much superior to CT by providing higher seed and stalk yield, land and water-use efficiency. It also improved infiltration rate, organic carbon, available N, P and K on a sandy loam soil and semi-arid climatic conditions in Central India.

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