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Water-use Efficiency and the Effect of Water Deficits under Different Planting Techniques on Productivity and Profitability of Chickpea (*Cicer arietinum* L.) in *Typic Ustochrept* Soil of Morena Region of M.P.

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A B S T R A C T

Exploiting the production potential of chickpea through agronomic management is one of the alternatives to feed the pulse requirements of ever growing population. For this, efficient planting methods have contributed substantially to the spectacular increase in chickpea yield and to improve water productivity per unit of water use. In order to study the planting methods in chickpea was at the domain of R.V.S. Krishi Vishwa Vidyalaya - ZARS, Morena, Madhya Pradesh during Rabi 2017-18 and 2018-19. The experiment was laid out in randomized block design with fifteen replications means farmer as a replication. The treatment consisted of three planting methods T_1- Flat Beds (farmer practices), T_2- Furrow Irrigated Raised Beds 60cm (FIRB 60cm), and T_3- Furrow Irrigated Raised Beds 120cm (FIRB 120cm) in this way experiment was laid out. The study revealed that the values of growth contributing characters viz., nodules number (6.1%), nodule dry weight (23%), shoot and root dry weight (8.7%) and root dry weight (15%) and growth, yield and yield attributes like branches per plant (26.8%), pods per plant (19.3%) and seed yield (30.3%) under of chickpea were increasing significantly with FIRB 60 cm planting method (T_2) followed by FIRB 120cm planting method (T_3) and significantly superior over rest of the treatments (Flat beds farmer practices T_1). The maximum gross return and net return were noted under T_2 FIRB 60cm (Two rows of chickpea sown on the shoulders of the beds). The highest benefit cost ratio was recorded in T_2 FIRB 60cm followed by T_3 FIRB 120cm they proved Furrow Irrigated Raised Beds method were more remunerative then other treatments. Similarly, Furrow Irrigated Raised Beds (FIRB system)also improved water productivity as saving of irrigation water up to 29.52% was recorded under FIRB planting over that in flat beds. Hence, it was concluded that treatment T_2 (Furrow Irrigated Raised Beds with pair row of crop at 30 cm spacing on one bed) was economically feasible as compared to other methods of sowing of chick pea.

Introduction

Enhancing productivity of pulses has been the major concern for meeting protein malnutrition in India. The country's demand for pulses by 2020 is expected to reach 24 million tonnes. Among the potential pulse crops in the country, Chickpea (*Cicer arietinum L*.) is the premier pulse crop grown in 9.53 million ha with annual production of 9.33 million tonnes with an average productivity of 951 kg ha^{-1} (Annon, 2016-17). Chickpea is mainly grown during Rabi season in India under diverse production systems including both rain fed and irrigated, but its maximum area and production is mostly confined to Madhya Pradesh, Rajasthan, Maharashtra, Karnataka, Andhra Pradesh and Uttar Pradesh. In Madhya Pradesh chickpea occupy 2.6M ha area which contribute 2.8 million tonnes production, but average productivity is very low as compared to potential yield. Moreover, potential morpho-physiological traits in plants viz., water use efficiency (WUE), deep root system, higher relative biomass and harvest index, osmotic adjustment of chickpea are advantageous under water scarce situation (Chaudhury *et al.,* 2005).

Despite all this, crop experiences terminal drought during seed development stage as it is invariably grown on residual soil moisture after a preceding rainy crop, thereby making the terminal moisture stress as the major constraint in achieving potential productivity of chickpea (Singh *et al.,* 2010). Under such situations, photosynthetic activity of leaves is hampered for the want of nitrogen and thus, seedling is affected (Davies *et al.,* 2000). Therefore, a judicious management of available soil moisture through in-situ conservation a suitable land configuration viz., furrow irrigated raised bed system (FIRBS) improves crop productivity (Panwar and Basu, 2003).

Furrow Irrigated Raised beds technique has recently emerged as the most potential resource conserving technology in Indo-Gangetic plains of NW India under rice-wheat cropping system. Change over from growing crops in flat to ridge-furrow system of planting crops on raised bed alters the crop geometry and land configuration, offers more effective control over irrigation and drainage as well as their impacts on transport and transformations of nutrients, and rainwater management during the monsoon season. It is a method in which accommodating crop rows on both sides of furrow by increasing ridge spacing, thereby a common furrow is used for irrigation of two rows. In FIRB system, water moves horizontally from the furrows into the beds and is pulled upwards in the bed towards the soil surface by capillarity, evaporation and transpiration, and downwards largely by gravity. Raised bed planting of cereals, pulses and vegetables, on an average, increased yield by 24.2 per cent and saving of irrigation water by 31.2 per cent (Connor *et al.,* 2003). The major concern of this system is to enhance the productivity and save the irrigation water. Potential agronomic advantages of beds include improved soil structure due to reduced compaction through controlled trafficking, reduced water logging and timely machinery operations due to better surface drainage. Beds also create the opportunity for mechanical weed control and improved fertilizer placement (Singh *et al.,* 2002). In raised bed planting systems due to compaction of soil by tractor tyre in furrows causes faster movement of water and also lesser area to be covered for irrigation (40%).So, small quantity of water can be applied over large area through bed planting and depending up on soil type water saving ranges from 20 to 40%. Moreno *et al.*, (1993) reported that an increased water use efficiency and 35% reduction in irrigation water requirement in wheat grown under raised bed planting systems in Mexico and improvement in yield by 10% with irrigation application in furrows as compared to flood irrigation. The additional advantage of the system is that additional irrigation at grain filling can be made which generally results in lodging under flat system. Easy and uniform germination as well as growth and development of plant are provided by manipulation of sowing method. Further, land configuration increases water-use efficiency (Chiroma*et al.,* 2008). The superiority of raised bed method of sowing could be ascribed to proper drainage of excess water coupled with adequate aeration at the time of irrigation. Pramanik and Singh (2006) reported that crop planted on raised bed recorded significantly better growth than that planted on flat beds. They further concluded that raised bed planting significantly increased branching, nodulation and root growth.

Chickpea is also susceptible to water stagnation due to flood irrigation or rainfall even for a shorter period during the crop growth. Several scientific studies indicated that probability of 10-40% loss in crop production with increase in temperature by 2050 and less water availability in district Morens, Madhya Pradesh. To overcome the problem of water logging due to flooding or aberrant weather with higher precipitation, the novel strategy is to sow the crop on beds under furrow irrigated raised bed (FIRB) (Kumar *et al.,* 2012;Bhuyan*et al.,* 2012).Connor *et al.,* (2003) showed that crops planted on bed gave higher grain yield i.e. maize (37.4 %), urdbean (33.6), mungbean (21.8 %), greenpeas (14.5 %), wheat (6.4 %), rice (6.2 %), pigeonpea (46.7 %) and chickpea (37.0 %) as compared to flat planting. Patel *et al.,* (2018) also found that raised bed planting reduces the requirements for seed rate and provides favourable environment for the growth and development of pulse crops. Under normal condition in IndoGangetic plains, the crop needs at the most 2 irrigations coinciding with pre-flowering and pod development stages. There was also saving in seeds and fertilizer to the extent of 25-30% following raised bed system of planting (Kumar *et al.,* 2012). Hence, the present investigation was undertaken to refine the technological gap in chickpea concerning seed bed configuration so far as their effects on the crop productivity and profitability are concerned in Grid region of Madhya Pradesh.

Materials and Methods

The field experiment was conducted at different villages of Morena district, Madhya Pradesh viz. Santha, Barouli, Hadbanshi and Lalbansin the block Jouraduring Rabi 2017-18 and 2018-19 to evaluate the productive performance of chickpea under different land configurations. The study area lies 26°28′N–latitude and 77°59′E—longitude with an altitude 179 m. The climate of the study area of Morena is semi-arid tropical receiving an annual rainfall of700 mm (constituting 44% of pan evaporation) of which about 80% is received during the monsoon period. The mean annual maximum and minimum temperature of 49 and -1°C respectively (Figure 1). During the study periods (2017-18 and 2018-19) annual rainfall were 395.3 and 641.4 mm, respectively. District Morena comes under in tropical zone of Madhya Pradesh which is more vulnerable to climate shocks and more than 70 per cent population still dependent on agriculture. Climate change is being seen as a serious threat to agricultural productivity and farmer livelihood in the district. The mid and late rainy season drought, frost, terminal drought extreme events in the last 10 years were seen in the district. The rainfall was become more erratic and reduced number of rainy days; thus increasing the risk of drought damage to crops.

The predominant soil at the experimental site is classified as *Typic Ustochrept*. Soil samples for 0–15 cm depth at the site were collected and tested prior to applying treatments. Soils of the experimental site is sandy loam in texture with electrical conductivity 0.17 -0.25 dS m^{-1}, pH 7.6-8.1, organic carbon 0.31-0.54%, available N 150-210 kg ha^{-1}, P 14.8 -20.4 kg ha^{-1}, K 370-461 kg ha^{-1} (three nutrients are low), S 8.5 – 16.3 kg ha^{-1}, Zn 0.52- 2.1 mg kg^{-1}, B 0.79- 2.26 mg kg^{-1},Fe 6.94- 12.8mgkg^{-1}, Mn 7.8-14.6 mg kg^{-1} and Cu (0.56-1.1 mg kg^{-1}). The field capacity and permanent wilting point of soil was 33.8% and 11.9% on dry weight basis (w/w) with bulk density of 1.48-1.55 Mg $m^{-3}$and the basic properties were low available nitrogen, low organic carbon, available phosphorus, and available potassium medium and slightly alkaline in reaction.

Soil samples of 0-15cm were collected from selected fields for determining soil properties at the initiation of the experiment.*Typic Usrtochrept* soils of the experimental site is sandy loam in texture with electrical conductivity 0.17 -0.25 dS m^{-1}, pH 7.6-8.1, organic carbon 0.31-0.54%, available N 150-210 kg ha^{-1}, P 14.8 -20.4 kg ha^{-1}, K 370-461 kg ha^{-1} (three nutrients are low), S 8.5 – 16.3 kg ha^{-1}, Zn 0.52- 2.1 mg kg^{-1}, B 0.79- 2.26 mg kg^{-1},Fe 6.94- 12.8mgkg^{-1},Mn 7.8-14.6 mg kg^{-1} and Cu (0.56-1.1 mg kg^{-1}). The field capacity and permanent wilting point of soil was 33.8% and 11.9% on dry weight basis (w/w) with bulk density of 1.48-1.55 Mg m^{-3}.

The experimental was laid out in Randomized Block Design (RBD) where three treatments were replicated fifteen times. The detail of treatments with their symbols three planting techniques (T_1- flat beds farmer practices; T_2- Furrow irrigated raised beds [FIRB 60cm]; and T_3- Furrow irrigated raised beds [FIRB 120cm] with an area of 4000m^2 each plot.Chickpea recommended seed rate of 75 kg/ha was used for the study. DAP was applied @ 100 kg/ha at the time of final land preparationand used appropriate *Rhizobium* + PSB inoculation. Furrow irrigated raised beds were prepared by using tractor drawn raised bed planter. Two rows of chickpea were own on the ridges of 60 cm and four rows on 120 cm raised beds, respectively. First irrigation was applied at the time of branching (35-40 days after sowing) and second irrigation at the stage of pod formation (90-95 days after sowing) through the furrow.Other cultural and plant protect ion practices were followed as per there commendation.

Observations on nodulation and root/shoot dry weight at 60 days after sowing (DAS) were recorded through destructive plant samplingand grain and biological yield were assess using standard procedures (Rana *et al.*, 2014).Water use efficiency (WUE)/ water productivity were also calculated following standard procedure.

The crop was harvested manually by serrated edged sickles at physiological maturity when pods had about 85% ripened spikelet and upper portion of branches look straw coloured. At the time of harvesting the grains were subjected to hard enough, having less than 16 per cent moisture in the grains. First of all, the border area was harvested. The harvesting of net plot area was done separately and the harvested material from each net plot was carefully bundled and tagged after drying for three days in the field and then brought to the threshing floor.

The bundle of harvested produce of each net plot was weighed after sun drying for recording biological yield. Threshing of each bundle of individual plot was done manually by wooden sticks. The grain yield of individual plot after winnowing was weighed. The quantity of straw/stover per plot was calculated by subtracting the weight of grains from biological produce. Yield of both grain and straw was expressed in q ha^{-1}.

The economics was computed on the basis of prevailing market price of inputs and outputs for each treatment. The total cost of cultivation of crop was calculated on the basis of different operations performed and materials used for raising the crop including the cost of fertilizers and seeds. The cost of labour incurred in carrying out different operations was also included. Statistical analysis of the data was done asper the standard analysis of variance technique for the experimental designs following SPSS software based programme, and the treatment means were compared at P<0.05 level of probability using t-test and calculating LSD values.

Results and Discussion

Nodulation

Improvement in nodule/plant, nodules fresh weight and dry weight per plant was recorded under both 60and120 cm FIRB planting systems over conventional flat beds (T_1). The increase in nodules number per plant at 60 DAS was maximum 6.1% under T_2FIRB60 cm followed by 2.5% inT_3 FIRB 120cm in comparison with T_1flat bedplanting (Table 1). Although highest nodules dry weight per plant was observed under T_2FIRB60cm planting (0.39 g per plant at 60 days after sowing) and was at par withT_3 FIRB120cm planting system, respectively. However, nodules dry weight per plant was significantly higher over T_1flat bed planting. FIRB planting facilitated better nodulation due to more favourable rhizospeheric conditions for plant growth. As there was a greater depth of surface soil with furrows enabling good drainage, rapid re-aeration of the root-zone occurred following an irrigation or rainfall event (Pramanik *et al.,* 2009; Pandey *et al.,* 2018). Relatively lower bulk density (30%) and higher infiltration rate (5%) from FIRB system in comparison to flat bed method could also be attributed to enhanced nodulation under FIRB planting (Aggarwal and Goswami, 2003).

Partitioning to shoot and root

Significant variation in shoot and root dry weight was observed due to different planting methods (Table 1).The maximum shoot dry weight per plant was recorded in treatment T_2 FIRB 60 cm (4.69 g per plant at 60 days after sowing). Similarly, root dry weight per plant was highest in treatment T_2 FIRB 60 cm planting method (0.93 g) followed by T_3 FIRB 120cm (0.89 g) and least under T_1flat bed (0.79 g) planting method, respectively. Moreover, improvement in root: shoot ratio was also recorded under treatment T_2 FIRB 60 cm over T_1flat bed planting method. Improvement in root: shoot ratio due to FIRB system over flat bed was 11% at 60 DAS. The improvement in root and shoot weight under FIRB 60 cm and FIRB 120 cm over flat bedmethod was mainly due to congenial soil environment and better soil depth. FIRB also encourage initial root and shoot growth of plant (Pramanik *et al.,* 2009). Higher root density and improved soil condition under FIRB system was also reported by Aggarwal and Goswami, (2003).

Growth, Yield and yield attributes

Plant height

Plant height was significantly influenced by various planting techniques at harvest all the stage of crop (Table 1). Maximum plant height was recorded with the furrow irrigated raised beds at 60cm width (T_2) [FIRB 60cm] which was statistically at par with the furrow irrigated raised beds at 120cm planting method (FIRB 120cm) and significantly superior to rest of the treatments of crop growth. Wider spacing particularly under in FIRB 60cm method recorded significantly taller plant than the closer spacing, due to the fact that under wider spacing, the plant get sufficient space above the ground (shoot) and below the ground (root) to grow as well as the increased light transmission in the canopy, leading to greater plant height. At harvest, the tallest plants were recorded in FIRB 60cm. It might be due to more space, sunlight and nutrients available to wider spaced plants of FIRB 60cm than close spaced plants (flat beds) which facilitated the plants to attain more height. Shrirame *et al.,* (2000) reported that the number of functional leaves and leaf area were higher under wider spacing, which increased the photosynthetic rate leading to taller plant.

The data pertaining to yield attributes as influenced by planting methods is depicted in Table 2. All the yield attributes viz., branches per plant, pods per plan and test weight are the resultant of vegetative development of the crop which determine yield were influenced by various planting techniques. The increase in yield attributes was mainly due to increase in photosynthesis activity of leaves, translocation of photosynthesis from source to sink and nutrients uptake under higher nutrients availability.

The minimum values of the entire yield attributes were observed in the treatment received deficit water due to flat beds because of plants did not get sufficient amount of moisture which resulted in poor yield attributes. This was also evidenced by studies of Kumar *et al.,* (2010) and Sridevi (2011).

Number of pods per plant is one of the most yield attribute. Similarly the grain is fertilized; fully ripened ovule of pods in a plant that ultimately contributes to grain yield. This excludes empty or sterile pods per plant. The weight of individual grain calculated from 1000 grain weight (test weight) is an important yield attribute which provides information regarding the efficiency with grain filling process took place. Thousand grain weight (1000 grain weight), as it is called the test weight of the desired output, is referred to be considered as one of the most significant agronomic parameters ever trusted that contributes in having a reconnaissance over the possible production of a lot (grain yield).

Yield is the resultant of coordinated interplay of growth characters and yield attributes. Yield was influenced significantly by adopting various planting methods. Table 2 advocated that the maximum yield attributes were recorded significantly superior in T_2 treatment as compared to all other treatments except T_3. Treatments $T_1$and T_3 were at par with each other; however, T_1 treatment which recorded minimum yield attributes. As a result, branches per plant were maximum in FIRB 60.0cm (5.6) followed by FIRB 120cm (5.4) and minimum was under flat bed planting method (4.1). To the contrary, pods per plant were significantly higher in FIRB 60 cm (19.3%) and FIRB 120 cm with 9.0% in comparison to that in flat beds.

The improvements in yield attributing parameters were due to better plant growth under furrow irrigated raised bed planting system. Similarly, significant improvement in seed yield of chickpea was recorded under furrow irrigated raised bed planting system (Mishra *et al.,* 2012a; Kumar *et al.,* 2015).The average maximum improvement in seed yield was recorded in FIRB 60 cm (43.4 %). Enhanced nodulation, root and shoot growth and yield attributing characters also resulted in higher grain yield of chickpea under improved planting system of FIRB raised bed (Rathore *et al.,* 2010;Bhooshan and Singh, 2014; Pandey *et al.,* 2018).

Table.1 Effect of Nodulation, shoot dry weight and root dry weight on chickpea under different planting method

Planting method	Nodules plant^{-1}	Nodules fresh weight plant^{1}(g)	Nodules dry weight plant^{-1} (g)	Shoot dry weight plant^{-1} (g)	Root dry weight plant^{-1} (g)	Root: shoot ratio
T_1 Flat bed	35.78	2.32	0.30	4.28	0.79	0.18
T_2 FIRB 60cm	52.45	2.47	0.39	4.69	0.93	0.20
T_3 FIRB 120cm	45.22	2.38	0.37	4.58	0.89	0.19
CD (P=0.05)	4.11	NS	0.04	0.28	0.05	-

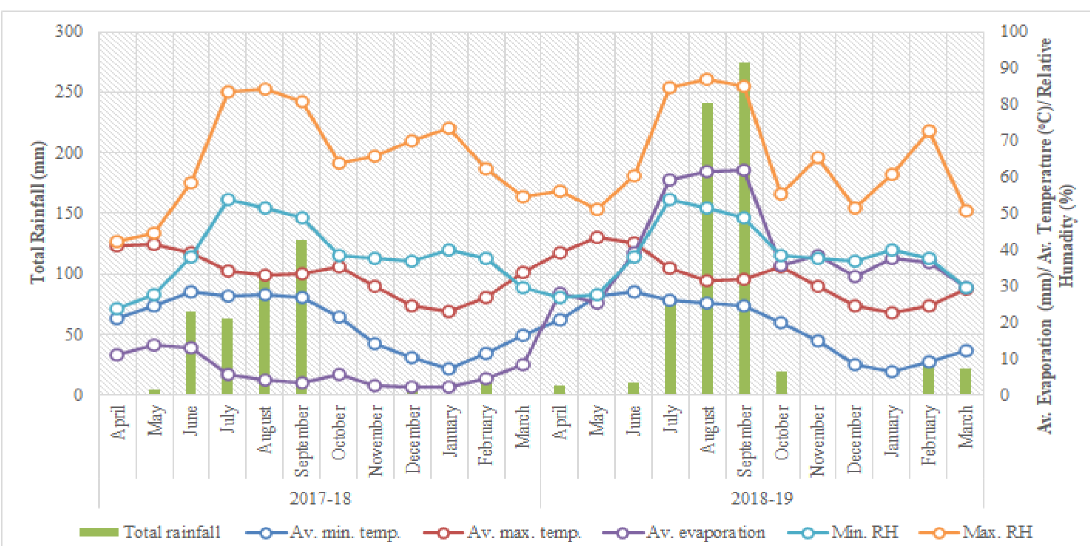
Table.2 Effect of different planting methods on growth and yield of Chickpea

Planting method	Plant height(cm.)	Branches plant^{-1}	Pods plant^{-1}	1000 seed weight (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1 Flat bed	45.40	4.1	52.50	222.42	15.76	27.26
T_2 FIRB 60cm	56.20	5.6	62.64	246.74	22.60	33.10
T_3 FIRB 120cm	53.60	5.4	57.25	238.61	19.81	31.32
CD (P=0.05)	3.4	0.6	3.8	7.3	1.43	1.91

Table.3 Effect of different planting methods on economics and water productivity of Chickpea

Planting methods	Gross income (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio	Total water use water m-^{3}	Water productivity (kg seed m^{-3} water)
T_1 Flat bed	77318	51518	2.99	2100	0.75
T_2 FIRB 60cm	110875	85075	4.29	1480	2.10
T_3 FIRB 120cm	97188	71388	3.76	1070	1.34

Fig.1 Monthly meteorological data during experimental years



Water Productivity and Profitability

Water productivity in different planting system was highest under FIRB 60 cm (2.10 kg/ha-m^3) followed by FIRB 120 cm (1.34 kg/ha-m^3) and least under flat bed planting method (0.75 kg/ha-m^3) [Table 3]. The higher water productivity under furrow irrigated raised bed system was mainly because of less application of irrigation water and higher yield than flat bed planting. The irrigation water requirement was lower in FIRB 120 cm (49.0%) and FIRB 60 cm (29.52%) over that in flood irrigation applied under flat bed system. Similar findings were also reported by (Pramanik *et al.*, 2009; Pandey *et al.*, 2014; Naresh *et al.*, 2015).

Profitability

The data indicated that the highest gross return (Rs.110875ha^{-1}), net return (Rs. 85075 ha^{-1}) and B: C ratio (4.29) was observed in the treatment T_2 FIRB 60cm (Table 2) due to increase in seed yield and more net return to the tune of 65.13%, respectively over T1flat bed system. Therefore, treatment T_2 FIRB 60cm proved better performance over rest of the treatment during the years of study. The result was conformity with the findings of (Pramanik *et al.*, 2009; Kumar *et al.*, 2015) who also realized higher economic return due to planting systems.

It is concluded from the foregoing discussion it is amply clear that precise planting techniques play a key role to improving crop-water productivity and resource saving in the sub -tropical climatic conditions of India. Planting techniques help maintaining production sustainability without any detriment to the environment. Agro-eco-region specific practical technologies need to be developed in the light of availability of various resources for making the best use of valuable data generated under tillage practices. The data acquired from the chickpea experiment revealed that planting methods had significant effects, of varying magnitude, on growth and yield attributes and yield. Successful precise planting technique mechanism would depend on a concerted effort by a multitude of factors (public and private) working in a participatory mode is the need so as to enhance the production and economic viability of millions of smallholder farms currently struggling with declining soil fertility and poor management of plant nutrients. Thus, the overall performance of chickpea was superior in furrow irrigated raised bed (FIRB) over other planting systems with respect to nodulation, root/shoot growth, branching, podding, yield and economics as FIRB60cm saved 29.52% irrigation water over flat bed planting.

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