2,500 ppm at 150 DAS increased the harvest index. The exogenously applied ethylene as defoliant could have resulted in remobilization of metabolites and assimilates from non-economic part to seed-cotton yield. Similar results were reported by Sarlach *et al.* (2010) in cotton.

Economic analysis

Regarding cost of cultivation and net returns, the application of ethrel @ 2500 ppm at 150 DAS (D_6) recorded the highest net income (Table 4). The lowest net returns were obtained under the control plot (D_9) during both the years. The benefit: cost ratio was also found higher with application of ethrel @ 2,500 ppm at 150 DAS (D_6), while the lowest obtained with the control plot (D_9).

Application of defoliant, ethrel @ 2,500 ppm at 150 DAS recorded the highest percentage of senescence attributes and seed-cotton yield. Thus, it brings synchronized maturity in rainfed cotton and would favours the mechanical harvesting. Ethrel can be applied as defoliant in rainfed cotton with a concentration of 2,500 ppm on 150 DAS to induce leaf senescence and synchronized maturity. Ethrel @ 2,500 ppm at 150 DAS was found to be the best agronomic management practice in order to enhance synchronized maturity, yield and economic returns in cotton under rainfed vertisols.

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Research Paper

Response of mechanization levels and *in-situ* rainwater-conservation practices, their dynamics on production potential of soybean [*Glycine max*] under rainfed condition

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ABSTRACT

A field experiment was conducted on medium black soils at All-India Coordinated Research Project for Dryland Agriculture, Parbhani, Maharashtra, during the rainy (*kharif*) seasons of 2016 to 2018, to evaluate the effect of mechanization practices coupled with different *in-situ* rainwater-conservation practices on soybean [*Glycine max* (L.) Merr.] . The treatments comprising complete mechanization, partial mechanization and traditional methods of cultivation (flatbed) were evaluated for rainfed 'MAUS 162' soybean [*Glycine max* (L.) Merr.] along with subplot treatments of broad bed and furrow (BBF), ridges and furrow and flatbed. Complete mechanization in soybean resulted in higher seed yield, gross monetary returns, net monetary returns, benefit: cost ratio and rainwater-use efficiency. *In-situ* moisture-conservation practices such as BBF and ridges and furrow method of sowing recorded the highest seed yield (25.23 and 15.71% increase), net monetary returns (51.95%, 30.7%) and rainwater –use efficiency (25% and 15%) as compared to traditional method of cultivation. Complete mechanization along with BBF method of sowing in soybean proved be significantly superior to all treatment combinations with respect to seed yield, net monetary returns and rainwater-use efficiency. The highest energy output-input ratio (10.2) was observed in complete mechanization with BBF method of sowing.

Keywords: Broad bed and furrow, Economics, Energy, Infiltration, Mechanization, Ridges and Furrow, Seed yield, Soybean

Soybean is most important rainy (*kharif*) season oilseed crop, cultivated on an area of 10.60 million ha, with a production of 10.98 million tonnes and productivity of 1036 kg/ha during 2017, (FAO, 2019). The widely fragmented and scattered land holdings in many parts of the country need to be consolidated to give access for their owners to the benefits of agricultural mechanization. Mechanization enhances productivity besides reducing human drudgery and cost of cultivation. Mechanization also helps in improving utilization efficiency of other inputs, safety and comfort of the agricultural worker and improvements in the quality of seed. Increased use of mechanical land preparation and threshing attests (Nadre, 2005) to the farm-level profitability.

Production suffers due to improper seedbed preparation, depth of seed, delay in sowing and harvesting. Mechanization enables the conservation of input through precision metering, ensuring better distribution, reducing quantity needed for better response and prevention of losses or wastage of inputs applied. Uniform seed spacing and depth result in better germination and emergence and increase yield by minimizing competition between plants for available light, water and nutrients (Karayel and Ozmerzi, 2008). In traditional method of sowing, proper and uniform placement of seed in field cannot be achieved by labour. But it can be possible with mechanical sowing.

In India, area and production of soybean are dominated by Madhya Pradesh followed by Maharashtra and the majority of area is rain dependent. Soil moisture is the most limiting factor for crop production (Virk *et al*., 2019).

Considering these facts, a field experiment was conducted to evaluate the effect of levels of mechanization and moisture-conservation practices on productivity and economics of soybean, infiltration characteristic under various levels of mechanization and moisture-conservation practices and also energy output: input ratio under various lev-

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els of mechanization and moisture-conservation practices.

MATERIALS AND METHODS

The experiment was conducted during the rainy (*kharif*) seasons of 2016–18 at experimental farm of All India Coordinated Research Project (AICRP) for Dryland Agriculture, Parbhani, Maharashtra. The district has been classified as rainfed agro-ecosystem and soybean-based production system with an average rainfall of 892 mm. The cultivated fields in the Parbhani district are normally having slope in the range of 0.5 to 1% with good surface-drainage conditions. The experimental soil was medium black with *p*H 8.1, organic carbon 0.50 % and contained low nitrogen (150 kg/ha), low phosphorus (12.1 kg/ha) and high potassium (498 kg/ha). The experiment was laid out in a split-plot with 4 replications. The gross plot size was 4.5 m × 18.0 m and net 3.6 m × 15.0 m. The recommended dose of fertilizer applied was 30 : 60 : 30 N : P : K Kg/ha with FYM 5 t/ha.

The experiment was executed with 3 main plot treatments, viz., T_1, complete mechanization (ploughing to harvesting and threshing by machine); T_2, partial mechanization (ploughing to sowing by machine, weeding and harvesting manually, threshing by machine); and T_3, traditional method (by bullock-drawn and manually) with 3 subplot treatments, viz., S_1, broadbed and furrow (BBF), S_2, ridges and furrow; and S_3, flatbed. Soybean was sown using seed drill and BBF planter. Soil moisture availability was determined by gravimetric method using screw auger. The infiltration rate under different level of mechanization was determined by conducting infiltration test using double ring infiltrometer.

Farm operations and machineries used under various level of mechanization

The information on operation-wise type of implements used for conducting various field operations under different level of mechanization is presented in Table 1.

All the data obtained in the experiment for 3 consecutive years of investigation were statistically analyzed using the F-test as the procedure given by Gomez and Gomez (1984), and critical difference values at P=0.05 were used to determine the significance of differences between means.

RESULTS AND DISCUSSION

The pooled data over 3 seasons with respect to soybean seed yield, net returns, benefit: cost ratio and rainwater-use efficiency are presented in Table 2.

Soybean seed yield

The effect of mechanization practices on soybean yield was found significant. The treatment T_1, i.e. complete mechanization, recorded the highest soybean yield which was found significantly superior to rest of the treatments. Similarly, soybean yield under partial mechanization was found significantly to over traditional method of cultivation.

The effect of land configurations on soybean seed yield was found significant. Soybean seed yield recorded by treatment soybean planted on BBF (S_1) was significantly superior to flatbed treatment and at par with soybean sown under ridges and furrow. Similar findings were also reported by Jadhav *et al.* (2012) and also concluded that *in-situ* moisture-conservation techniques were useful in enhancing soil water availability and increase in soybean yield.

Effect of mechanization and land configurations on economics

The effect of mechanization practices on soybean gross (GMR) and net monetary returns (NMR) was found significant. Complete mechanization recorded significantly higher GMR and NMR than rest of the treatments. Partial mechanization was also significantly superior to traditional method of cultivation. Mechanization with different land

Table 1. Farm operations and machineries used under various levels of mechanization

List of Implements/machineries used			
Operations	Complete mechanization	Partial mechanization	Traditional method of cultivation
Ploughing	Tractor-drawn MB plough	Tractor-drawn MB plough	Bullock-drawn plough
	Tractor-drawn Harrow	Tractor-drawn harrow	Bullock-drawn harrow
Sowing	BBF planter	BBF planter	Bullock-drawn BBF
	Seed drill (tractor drown)	Seed drill (tractor drown)	Bullock-drawn seed drill
Spraying	Tractor drawn boom spray	Manual	Manual spray
Interculture/ weeding	Through tractor	Bullock-drawn hoe	Manual
Harvesting	Combine Harvester	Harvest manual and threshing by thresher	Manual harvesting and threshing

MB, mould boord; BBF, broad-bed and furrow configurations increased the seed yield, as also reported by Jadhav *et al.* (2012).

The NMR was significantly higher with BBF than the soybean sown on flatbed and soybean sown on ridges and furrow. The similar trend was observed in case benefit: cost (B: C) ratio. Significantly, better benefit: cost ratio was observed under complete mechanization as compared to traditional cultivation practice (flat bed). Khobragade *et al.* (2011) and Khambalkar *et al.* (2014) also obtained similar results with respect to enhancement in soybean yield.

The rainwater-use efficiency (RWUE) was worked out based on soybean seed yield and effective rainfall of the corresponding year. The RWUE (kg/mm-ha) of the various land configurations was differed. The highest RWUE was observed (4.31) with S_1 treatment, followed by S_2 (4.12) and S_3 (3.53), whereas within the different mechanization practices T_1 recorded highest RWUE (4.49) followed by T_2 (4.04).

Different sowing methods like raised bed, ridges and furrow in soybean and found conserve more moisture and result in increased yield than traditional sowing (Ram *et al.,* 2011). The studies conducted on performance of tractor-drawn BBF for soybean (Singh *et al*., 2011) showed that more moisture was conserved with this sowing method and increase in yield. The effect of mechanization with different land configurations on yield and *in-situ* moisture conservation of soybean was studied by Jadhav *et al.* (2012), who reported that yield was increased due to mechanization and adoption of various land configuration practices.

Infiltration characteristics

The infiltration tests were conducted under various levels of mechanization and land configurations.

Data presented in Table 3 indicated that the maximum infiltration rate was observed under complete mechanization treatment, followed by under partial mechanization and traditional method of cultivation. The graphical representation of infiltration characteristic is shown in Fig.1 and Fig. 2;

The soil moisture under each treatment combination was observed and mean soil moisture during the crop growth season is presented in Table 4.

The highest moisture content was observed under the treatment of complete mechanization with BBF and ridges and furrow as compared to flatbed treatment (Table 4). All land configurations were found effective in increasing the soil-moisture status.

Table 2. Soybean seed yield, net returns, benefit: cost ratio and rainwater use efficiency as influenced by various treatments.

Treatment	Pooled mean data			
	Soybean seed yield (t/ha)	Net returns ($\times 10^3$₹/ha)	Benefit:cost ratio	Rainwater-use efficiency (kg/ha/mm)
T_1, Complete mechanization	2.3	40.07	2.34	3.49
T_2, Partial mechanization	2.1	35.21	2.23	3.22
T_3, Traditional method	1.9	30.04	2.09	2.88
SEm±	0.074	1.52	0.03	0.08
CD (P=0.05)	0.25	4.60	0.09	0.22
S_1, BBF	2.3	41.50	2.45	3.50
S_2, Ridges and Furrow	2.1	35.70	2.23	3.22
S_3, Flat bed	1.8	27.31	1.95	2.80
SEm±	0.068	1.74	0.07	0.08
CD (P=0.05)	0.206	5.26	0.20	0.25
Interaction effect (T × S)				
SEm±	0.10	1.69	0.08	0.09
CD (P=0.05)	0.31	4.96	0.24	0.28
Mean	2.09	35.02	2.22	3.16

BBF, broad-bed and furrow

Table 3. Infiltration rate (cm/hr) under each treatment combinations

Land configurations/mechanization	S_1, BBF	S_2, Ridges and furrow	S_3, Flat bed
T_1, Complete mechanization	2.3	2.2	1.9
T_2, Partial mechanization	2.2	2.1	1.85
T_3, Traditional method	1.85	1.90	1.8

BBF, broad-bed and furrow

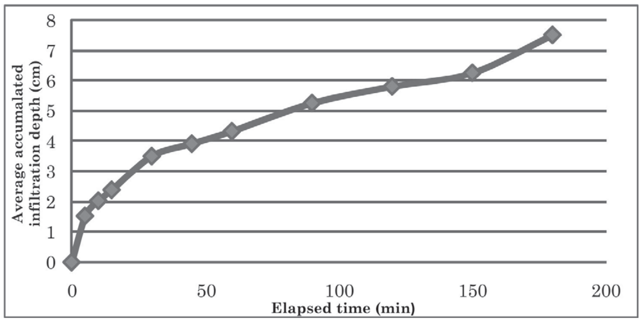

Fig. 1. Cummulative infiltration rate (cm)

The pooled data on yield-contributing characteristics as influenced by various levels of mechanization and land configuration are presented in Table 5.

Complete mechanization and partial mechanization recorded significantly higher growth and all yield attributes over the control, i.e. traditional method of cultivation and flatbed sowing (Table 5). Complete mechanization recorded significantly higher plant height, pods/plant, branches/plant and seed weight/1,000 seeds over traditional method and found at par with partial mechanization. Similarly, land configuration of BBF recorded significantly higher plant height, pods/plant, branches/plant and seed weight/1,000 seeds over flatbed treatment and found at par with ridges and furrow treatment.

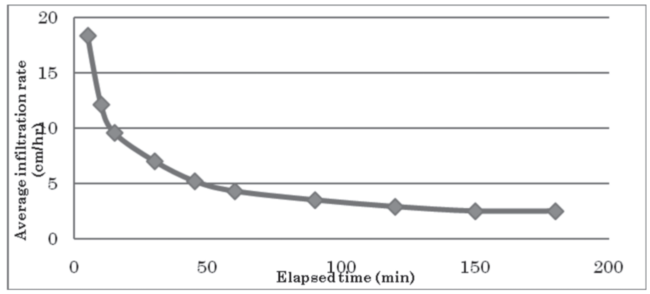

Fig. 2. Graphical representation of basic infiltration rate

Table 4. Mean Soil moisture (%) under various treatment combinations.

Land configurations /Mechanization	S_1, BBF	S_2, Ridges and furrow	S_3, Flat bed
T_1, Complete mechanization	30.60	28.65	25.00
T_2, Partial mechanization	29.72	26.76	24.06
T_3, Traditional method	26.50	25.50	23.50

BBF, broad-bed and furrow

Table 5. Yield-contributing characteristic under different treatments

Treatment	Pooled mean data			
	Plant height (cm)	Pods / plant	Branches/ plant	1,000-seed weight(g)
T_1, Complete mechanization	70.4	69	36	128
T_2, Partial mechanization	69.2	64	34	115
T_3, Traditional method	65.8	59	31	96
SEm±	1.05	0.46	0.52	5.5
CD (P=0.05)	3.2	1.83	1.57	16.8
S_1, BBF	69.5	69	34	132
S_2, Ridges and furrow	67.5	66	31	118
S_3, Flat bed	62.2	58	28	98
SEm±	1.32	0.59	0.70	6.3
CD (P=0.05)	4.09	2.49	2.14	18.8
Interaction effect ($T \times S$)				
SEm±	1.62	1.03	0.65	7.2
CD (P=0.05)	4.83	3.20	2.15	21.2
Mean	67.43	64	32	1149

Table 6. Total energy input, output and energy output: input ratio under various levels of mechanization.

Treatment	Total input energy (MJ/ha)	Total output energy (MJ/ha)	Ratio
Complete mechanization	6,876	70,722	10.2
Partial mechanization	6,901	66,729	9.6
Traditional method of cultivation	6,368	42,110	6.6