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Influence of land configuration and fertilization techniques on soybean (*Glycine max* (L.) Merrill.) productivity, soil moisture and fertility

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Influence of land configuration and fertilization techniques on soybean (*Glycine max* (L.) Merrill.) productivity, soil moisture and fertility

Abstract: An experiment was conducted to investigate the impact of flatbed (FB), ridges and furrows (RF) and broad bed furrows (BBF) combined with recommended fertilizer dose $N_{30}P_{60}K_{30}$ kg ha^{-1} (F_1), 75 % NPK (F_2), 125 % NPK (F_3), 75 % NPK + 25 % N through farm yard manure (FYM)-F_4, 75 % NPK + 2 sprays of micro nutrient mixture (Fe, Zn, Cu, Mn, B and Mo) - 0.5 % at 35 and 60 days after sowing (DAS)-F_5 and 75 % NPK + 2 sprays of KNO_3 - 0.5 % at 35 and 1.0 % at 60 DAS (F_6) on the productivity of soybean in a split plot design. BBF stored 14.15 % more soil water and produced 1058.97 kg ha^{-1} more yield than FB. A significant 3.76 kg ha^{-1}-mm rain water use efficiency was notice in BBF compared to FB. The yield increment recorded under F_6 was 15.6 % higher than F_1. Grain nitrogen and oil contents were highest in F_3. The residual soil fertility was much improve by F_3 and F_5. Our result demonstrated that the combination of BBF and F_6 were the best technique to increase soybean yield in the Vertisol soil.

Key words: foliar fertilization; land configuration; soil moisture; soybean nutrition; yield

Vpliv priprave zemljišča in gnojilnih tehnik na pridelek soje (*Glycine max* (L.) Merrill.), na vlažnost in rodovitnost tal

Izvleček: Poskus z deljenkami je bil narejen za preučitev načinov priprave zemljišča kot so ravno zemljišče (FB), grebeni in brazde (RF) in široki grebeni (BBF) v kombinaciji s priporočenimi odmerki gnojenja: $N_{30}P_{60}K_{30}$ kg ha^{-1} (F_1), 75 % NPK (F_2), 125 % NPK (F_3), 75 % NPK + 25 % N kot hlevski gnoj (FYM) ($F_{4)}$, 75 % NPK + 2 kratno pršenje z mešanico mikrohranil (Fe, Zn, Cu, Mn, B in Mo), 0,5 % 35 in 60 dni po setvi (DAS)(F_5) in 75 % NPK + 2 pršenja s KNO_3 - 0,5 % 35 in 1,0 % 60 dni po setvi DAS (F_6) na pridelek soje. Pri BBF se je ohranilo 14,15 % več talne vode in dalo za 1058,97 kg ha^{-1} več pridelka kot FB. Pri BBF je bila ugotovljena tudi značilno večja učinkovitost (3,76 kg ha^{-1}-mm) izrabe deževnice kot pri FB. Povečanje pridelka je bilo pri F_6 za 15,6 % večje kot pri F_1.Vsebnost dušika in olja v zrnih sta bili največji pri F_3. Rodovitnost tal se je znatno povečala pri F_3 in F_5. Rezultati so pokazali, da je bila kombinacija BBF in F_6 najboljša tehnika za povečanje pridelka soje v tleh na vertisolu.

Ključne besede: foliarno gnojenje; oblikovanost zemljišča; vlažnost tal; gnojenje soje; pridelek

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1 INTRODUCTION

Soybean (*Glycine max* (L.) Merrill.) is the most important oil seed crop in India, owing to its several domestic and industrial uses, besides its use in numerous food preparations and animal feed formulations. Soybean accounts for about 53 % of the world production share among the oilseed crops, and has therefore, occupied an important place in most farming systems in the Marathwada region of Maharashtra State, India (Talukdar & Shivakumar, 2016). However, under rain fed systems, soil moisture stress of 15-21 days at any growth phase of the soybean crop results in a significant yield loss in the Maharashtra State (Patil, 1992). These yield losses are especially severe in the early determinate genotypes (Chaturvedi et al., 2012). The drying and cracking nature of the vertisol soils in the region, coupled with their low fertility aggravates the situation (Keteku et al., 2016). To effectively manage the problem amidst irrigation difficulties, technologies targeted at soil moisture and nutrient conservation such as land layout are very crucial. Thus soil, water and nutrient conservation technologies are the key adaptation strategies to mitigate the rapid loss of moisture (Kurukulasuriya & Rosenthal, 2003); and help plants withstand the occurrence of short dry spells under rain fed farming. An earlier studies on soil management strategies, aimed to increase crop productivity revealed that, modification of land such as broad bed furrow, and ridges and furrows in vertisol soils were superior to flatbed under watershed development (Raut & Taware, 1997). It is noteworthy to also mention that, soybean is a high protein and energy crop, as such it has a high nutrient requirement. Unfortunately, the inadequate and imbalance fertilization practiced by farmers, also adds to the problem of decreasing yield (Chaturvedi et al., 2012).

Usually, the farmer's fertilizer programs focus solely on soil applied NPK, without plans for foliar application, however recent studies had shown the foliar fertilization enhance soybean yield (Gowthami & Rama, 2014; Chaturvedi et al., 2012). Others had also reported that micronutrients are essential for the optimum utilization of major nutrients, and also for the production of organic compounds (Gowthami & Rama, 2014; Intanon, 2013). Numerous previous studies had equally reported the impact of combine major and micro nutrients on crop yield (Keteku et al., 2018; Intanon, 2013; Salem & El-Gizawy 2012). Soybean is a focus crop for the realization of the Sustainable Development Goals (Shinde et al., 2009). Climate change threatens rainfall pattern and therefore, the achievement of the Sustainable Development Goals aimed at poverty and hunger reduction. Therefore our work is designed to investigate (i) the influence of land modification on soil moisture and soybean yield, and (ii) the effect of different fertilization techniques on soybean yield and soil properties. This is necessary to find the appropriate land configuration and techno-economic nutrient package for soybean production under such vertisol soil.

2 MATERIALS AND METHODS

2.1 EXPERIMENTAL SITE

The experiment was conducted at the experimental farms of the All India Coordinated Research Project on Dryland Agriculture (AICRP) station at Vasantrao Naik Marathwada Agriculture University (VNMKV), Marathwada, India, during rainy season, 2017. VNMKV is situated on a latitude and longitude of 19° 15' 28.0440" N and 76° 46' 25.4748" E respectively, and at 409 m above mean sea level. The average annual precipitation of the region is 963 mm, distributed in 48 rainy days, mostly during June – October. The mean maximum and minimum temperatures are 32.2 °C and 19.0 °C respectively. The total rainfall received during the trail was 308.4 mm, distributed in 35 rainy days. A total effective rainfall of 281.7 mm was recorded. Relative humidity was in the ranges of 81.8 % - 48.1 %, while that of mean bright sunshine was 6.7 hr. The mean evapotranspiration was 5.4 mm as well. The research soil was vertisol in classification (WRB), medium deep black, well drained, low in fertility, except K and levelled in topography. The soil nutrients and moisture contents at a depth of (0-20 cm) before the trial are shown in (Table 1). The pH of the soil was alkaline.

2.2 EXPERIMENTAL PLAN

The experiment was 2 factorial, conducted in split plot design with 3 replications. The treatments were

Table 1: Soil properties before the trial (sample size (n) = 3)

N	P	K	Fe	Zn	Cu	Mn	B	pH (1:1.5)	Moisture %
	%				mg/kg				
0.514	0.313	1.27	5.24	1.33	0.32	2.24	0.37	7.9	17.85

composed from 3 land configurations as main plots treatments and 6 fertilization strategies as subplots treatments, making a total of 18 treatment combinations. The 3 land configurations were; flatbed (FB), ridges & furrow (RF) and broad bed furrow (BBF), while the 6 fertilizers were a combination of urea, single super phosphate and murate of potash; recommended fertilizer dose $N_{30}P_{60}K_{30}$ kg ha^{-1} F_1 = 100 % by mass, 75 % NPK (F_2), 125 % NPK (F_3), 75 % NPK + 25 % N through 5 tons FYM ha^{-1} (F_4), 75 % NPK + 2 sprays of 0.5 % micro nutrient mixture (Fe, Zn, Cu, Mn, B and Mo)– 50 ml per 10 L water at 35 and 60 DAS (F_5) and 75 % NPK + 2 sprays of 0.5 % KNO_3 - 50 ml per 10 L water at 35 and 1.0 % - 100 ml per 10 L water at 60 DAS (F_6). Thus, 2500 ml for 0.5 % and 5000 ml for 1 % to 500 L water was used for ha.The KNO_3 contained 13 % and 45 % nitrogen and potassium, respectively. The gross and net plot sizes used were 5.4 x 6.0 m and 4.5 x 5.0 m, in length and width respectively.

The land was ploughed with a tractor drawn plough to a depth of 20 cm and harrowed twice before the preparation of the ridges and furrows, and broad bed furrows. The ridges measured 45 cm wide and 15 cm high while that of the broad bed furrows were 120 cm × 30 cm × 15 cm in width, length and height, respectively. The seeds of determinant soybean variety ('MAUS-162') were treated with *Rhizobium* culture *(Bradyrhizobium japonicum* (Kirchner 1896) Jordan 1982) and phosphate solubilizing bacteria (PSB), and sown at the recommended spacing of 45 × 5 cm^2. But on the broad bed furrows a planting distance of 37.5 × 5 cm^2 was used so as to obtain uniform plant population in all plots. A rate of 65 kg ha^{-1} was used, two seeds were dibbled per hill and thinned out after 14 DAS to maintain one seedling per hill. The solid fertilizers were applied by side placement method, 30 % was applied at sowing and the remaining 70 % applied at 30 DAS. The FYM was broadcasted and raked into the soil on the flatbed and broad bed furrows, but in the ridges and furrows, it was applied uniformly in the lines opened for sowing. The 'MAUS-162' seeds were sourced from the seed processing plant, VNMKV while the fertilizers, *Rhizobium* culture and PSB were obtained from AICRP, VNMKV. One spraying of Chloropyriphos 20 EC was performed to control leaf eating caterpillar. Two hand weeding and one hoeing were performed to control weeds and also loosen the soil for good aeration.

2.3 DATA COLLECTION

Before the trial, soil cores were collected from 12 spots on the research site at a depth of (0-20 cm) with the hand auger for the assessment of soil fertility and pH. The routine methods of Lu (1999) were followed for the determination of soil nutrients. Total nitrogen, phosphorus and potassium were determine by the Kjeldahl method, Bray's no. II method and Neutral N ammonium method, respectively. The wet digestion (nitric-perchloric digestion) method was adopted for the analysis of iron, zinc, copper, manganese and boron. Soil pH was measured at 1:1.5 solution ratio, using the electrode (H19017 Microprocessor) pH meter. Another soil cores were also taken from a depth of (0-15 cm and 15-30 cm) for the determination of soil moisture content. Using the gravimetric method, the percentage soil moisture content were calculated for each depth and the mean worked out using the formula in (Equation 1). 50 g of the sample soil was oven dried at 105 °C ± 5 °C for 12 h.

$$\text{Moisture \%} = (m_2 - m_1)/(m_2) \times 100 \qquad \text{(Eqn 1)}$$

Where; m_1 = mass of wet soil sample, m_2 = mass of oven dried soil sample

Fifteen representative sampled plants were randomly selected in each plot and tagged for the measurement of vegetative growth. Plant height, number of leaves, number of branches, leaf area and total dry matter mass per plant were measured after 30 DAS at 15 days interval. At each periodic data collection, two representative plant were uprooted, processed and oven dried at 72 °C ± 2 °C for 12 h for total dry matter measurement. However on the harvest day, total dry matter weight was again measured from the 15 sampled plants in each plot. Leaf area was measured from the sampled plants uprooted for dry matter studies. The leaves were aerated into leaflets and grouped into three class viz., small, medium and big. The maximum length and diameter of five leaflets from each group were measured using the hand held laser leaf area meter (CID Bio-Science, Inc.), and the method of Pawar (1978) was used to calculate the leaf area/plant (Equation 2).

$$\text{Leaf area/plant (dm}^2\text{)} = \sum_{i=0}^{n=3}(L \times D)K \qquad \text{(Eqn 2)}$$

Where; L, D, n and K are leaf length, leaf diameter, number of leaves and leaf area constant for soybean (0.689), respectively. Only the final values were reported here. Also, yield components namely; number of pod plant^{-1}, pod mass plant^{-1}, grain mass plant^{-1} and 1000 seeds mass were measured from the fifteen sampled plants. After harvesting (120 DAS), grain mass plot^{-1} and straw mass plot^{-1} were measured, all the plants in the net plots were consider. The values were later converted to grain yield ha^{-1}. The biological yield produce was determined as the summation of grain mass plot^{-1} and straw mass plot^{-1} and again converted into ha. Harvest index (HI) was calculated as indicated in (Equation 3).

HI % = (Biological yield (kg))/(Grain yield (kg)) × 100 (Eqn 3)

The protein and oil content of the seeds were determined for quality assessment, grain nitrogen content was estimated by the micro Kjeldahal method (A.O.A.C., 1975), and was converted into crude protein percentage by multiplying the percent nitrogen with 6.25. Soxhlet ether extraction method was used to estimate the oil content.

After the trial, soil samples were again sampled and the properties estimated by the same methods above. Rain water use efficiency (RWUE) was computed by the formula (Equation 4) and expressed in kg/ha-mm.

RWUE (kg ha^{-1}-mm) = (Yield kg ha^{-1})/(Moisture use(effective rainfall) mm) (Eqn 4)

2.4 STATISTICAL ANALYSIS

The data recorded were subjected to Analysis of Variance (ANOVA) using SPSS 21 statistical package. The variation between treatments means were quantified at a probability of 5 %. Duncan's Multiple Range Test (DMRT) analysis was performed and presented in tables, in alphabets with 'a' depicting highest value. Interactions between factors were not significant, hence not presented. Regression analysis was used to show the relationship between some variables.

3 RESULTS AND DISCUSSION

3.1 INFLUENCE OF LAND CONFIGURATION ON SOIL MOISTURE CONTENT

The impact of land configuration on soil moisture content (0-30 cm) was significant ($p < 0.05$) as shown in Figure 1. Soil moisture content increased gradually from 30 to 90 DAS in the BBF and RF, compared to FB which recorded a decrease at 90 DAS. At 30, 60, 75 and 90 DAS, BBF conserved the highest significant soil moisture of 19.86, 27.30, 23.55 and 20.43 %, respectively when compared to RF and FB. Similarly, RF stored a significant amount of moisture on 60 and 90 DAS (27.29 % and 18.30 %, respectively) than FB. The furrows between the BBF and RF prevented the runoff of rain water and enhanced the infiltration of water into the soil. Probably the size of BBF also enhanced water conservation, as it has less surface area for evaporation when compare to the RF. In-situ land management strategies that reduces water lost caused by runoff and evaporation, and improves water infiltration and storage would lead to increase the amount of water retained in the soil for crops (Singh et al., 2014). BBF conserved 14.15 % more water than FB. Our results agrees with the previous findings of Shinde et al. (2009), Bharambe et al.(1999) and Patil et al.(1992) that BBF and RF conserved more water than FB. According to Kumar et al. (2010), furrow irrigated bed planting systems, on an average retained 40 % more water, compared to FB planting systems. Consistently, Selvarajua et al. (1999) also reported 17 % more soil moisture in BBF compare to FB. In contrasts to our findings, Singh et al. (2018) reported 28.54 % soil moisture in RF and 27.58 % in BBF, nevertheless they similarly reported the least soil moisture in FB. The principal aim of land configuration are; the preparation of a conducive seedbed for seed germination and seedling growth, conservation of soil moisture that influences the infiltration characteristics of the soil, and also, provides adequate soil depth for optimum root growth and proper fertilizers placement. The land configuration that stores enough moisture will reduce soil moisture tension, while improving nutrient flow and their availability for crop uptake (Singh & Kumar, 2009). Our findings has demonstrated that BBF and RF can conserve more moisture than FB.

3.2 INFLUENCE OF TREATMENTS ON SOYBEAN GROWTH

The results in Table 2 showed that soybean growth variables were significantly ($p < 0.05$) influenced by the various land configurations and fertilizers strategies. Interaction between factors were not significant and were therefore not discussed. Soybean height and number of branches (55.98 cm and 4.95) respectively, were superior in BBF compared to RF and FB. However, leaf area plant^{-1} was equal between BBF and RF, while that of total dry matter produced did not significantly differ among the land layouts. But the greatest dry matter mass of 24.20 g was produced by BBF. The high growth observed in BBF and RF could be related to the availability of optimum soil moisture at the key vegetative phase of the crop. When soil moisture tension is low, the ability of crops to absorb nutrients and that of the soil to supply nutrients are optimal, and so, nutrients availability are improved (Singh & Kumar 2009). In addition, the BBF and RF could also provide adequate aeration and a good soil depth for root expansion and nutrient exploration (Singh et al., 2014). From our re-

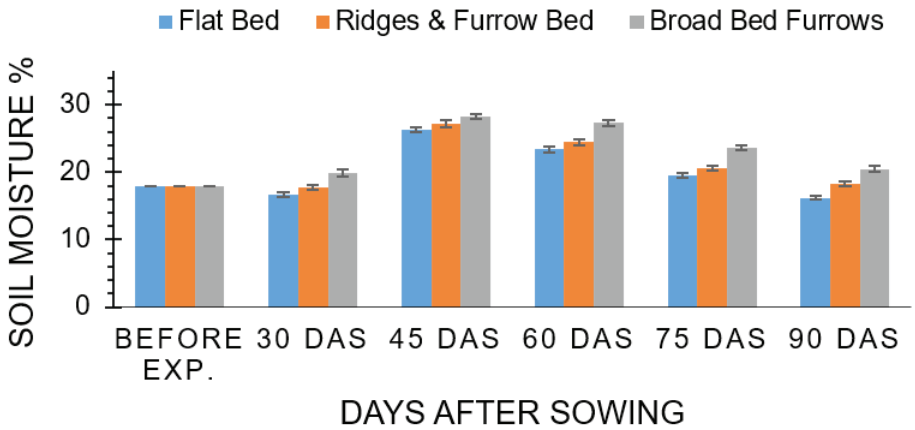

Figure 1: Effect of land configuration on soil moisture content (0-30 cm) during the trial

sults, it is evident that land layout had significant effect on growth.

Also, the application of F_6 (75 % NPK + 2 sprays of KNO_3- 0.5 % at 35 DAS and 1.0 % at 60 DAS) recorded the highest soybean height plant^{-1}, number of branches plant^{-1}, leaf area plant^{-1} and total dry matter mass plant^{-1} of 53.12 cm, 5.17, 22.10 dm^2 and 25.80 g respectively, but it was not significant when compared to F_3 and F_5 (dry matter). Increasing the NPK rate from F1 to F3 also increased soybean growth variables but did not give significant results. According to our result, F_1, F_2 and F_4 treatments had a similar effect on soybean growth. The performance of F_6 might probably be due to the rapid and efficient nutrients absorption resulting from the foliar spray of KNO_3 which contained 13 % N and 46 % K, while that of F_3 can be attributed to its higher NPK nutrients. Nitrogen particularly, is a principal constituent of protein, chlorophyll and the hormones which are essential for cell expansion and an increase in the vegetative apparatus of crops (Keteku et al., 2016; Nsoanya & Nweke, 2013). Besides having nitrogen which is an integral component of cell division in the fertilizers, the micronutrients do also influence cell division, chlorophyll construction and photosynthesis (Intanon 2013). This may probably explains why F_5 produced a similarly high total dry matter mass of 24.83 g, despite its low NPK content when compared to F_6 (25.80 g) and F_3 (24.50 g). It is noteworthy to indicate that the application of F_5 produced greater dry matter mass of 24.83 g when compared to F_3 (24.50); and a higher leaf area and dry matter mass when compare to F_1 (19.20 dm^2 and 23.30 g) respectively.

Previous studies by Khaliq et al. (2006) reported that, the sink capacity of a plant is mainly dependent on its vigorous vegetative growth; as such in our study, the treatments that recorded a large leaf area plant^{-1}, had more green areas available for the interception of active radiation during photosynthesis, for greater dry matter production (Azarpour et al., 2014). The regression analysis showed the impact of leaf area on dry matter produced by the fertilizers (R^2 = 0.8361) as shown in Figure 2.Dry matter production responded positively to an increase in leaf area plant^{-1}. Our results are also in agreement with Raj & Mallick (2017), in their studies the application of 80 kg N ha^{-1} + mixed spray of 0.203 % $Ca(NO_3)_2$ + 0.25 % KNO_3 produced the maximum leaf area index values (1.748 and 1.592), dry matter accumulation (1404.3 and 1288.8 g m^{-2}) and crop growth rate (27.87 and 25.68 g m^{-2} day^{-1}).

3.3 INFLUENCE OF TREATMENTS ON SOYBEAN YIELD COMPONENTS, YIELD, QUALITY AND WATER USE EFFICIENCY

The data in Table 3 showed a significant ($p < 0.05$) impact of land configuration and fertilizer on soybean yield components. Interactions between the factors were not significant. Pod mass plant^{-1}, grain mass plant^{-1} and 1000 seeds mass were significantly influenced by the different land configurations. The highest (12.32 g, 5.09 g and 85.56 g) respectively, were produced by BBF. This resulted to its greatest grain yield of 1058.97 kg ha^{-1} as well, but it was comparable to RF (1026.77 kg ha^{-1}) as shown in the Table 4. The soybean yield were in accordance with the vegetative growth record by the land configurations. BBF significantly increased grain yield by 8.8 %, when compared to FB. Straw yield, biological yield and harvest index did not vary significantly among the land configurations, nevertheless the greatest values were observed in BBF, and was followed by RF. A similar results had been previously reported in

Table 2: Influence of treatments on soybean growth

Treatments	Plant height plant^{-1} (cm)	Number of leaves plant^{-1}	Number of branches plant^{-1}	Leaf area plant^{-1} (dm^2)	Total dry matter mass plant^{-1} (g)
Land Configurations					
FB	46.83^{b}	16.68	3.82^{c}	17.98^{b}	23.20
RF	49.60^{b}	19.52	4.05^{b}	18.90^{ab}	23.72
BBF	55.98^{a}	19.53	4.95^{a}	21.47^{a}	24.20
CD @ 5 %	3.51	NS	0.19	2.63	NS
Fertilizers					
F_1	50.90^{ab}	18.43	4.10^{cd}	19.20^{bc}	23.30^{ab}
F_2	46.57^{b}	16.97	3.70^{e}	17.40^{c}	22.23^{b}
F_3	53.67^{a}	19.20	4.47^{b}	20.47^{ab}	24.50^{ab}
F_4	49.44^{ab}	17.60	3.93^{de}	18.03^{c}	21.57^{b}
F_5	51.13^{ab}	19.10	4.27^{bc}	19.50^{bc}	24.83^{ab}
F_6	53.12^{a}	20.17	5.17^{a}	22.10^{a}	25.80^{a}
CD @ 5 %	5.42	NS	0.32	2.22	2.72

Note: mean values with different superscript letter within each column denotes significance ($p < 0.05$) between different groups. CD = critical difference between means; NS = non-significant (n = 15)

other crops. In a study, Pramanik et al. (2009) reported a significant 16.8 % and 15.9 % rise in chickpea grain yield under raised bed planting over flatbed planting, in two seasons. According to Selvarajua et al. (1999) also, planting on BBF increased sorghum and pearl millet yields by 34 % and 33 % respectively, compared to FB. This they ascribed to the optimum water storage and safe disposal of excess rain water by BBF. Among all the in situ soil moisture conservation techniques, rain water use efficiency was the highest (3.76 kg ha^{-1}-mm) in BBF as well (Table 4). It is evident from the Table 4 that, an increase in water use efficiency corresponded to a greater soybean yield. When water utilization increased, nutrient uptake was enhanced by the mass flow process. Previous work of Lomte et al. (2006) also showed that, opening of furrows in every row recorded the highest water use efficiency of 3.15 kg ha^{-1}-mm than flat bed.

Among the fertilizers also, the application of F_6 recorded the greatest yield components; pod number plant^{-1} (30.65), pod mass plant^{-1} (13.40 g), grain mass plant^{-1} (5.36 g) and 1000 seeds mass (95.56 g). However, grain yield ha^{-1} was on a par between F_6 (1160.33 kg) and F_5 (1086.50 kg). A similar trend was noticed for straw yield and biological yield between the two treatments, and were followed by F_3. In addition, an increase in NPK rate from F1 to F3, also significantly increased grain yield by 2.3 % (Table 4). Additionally, the yield increment realized for F_6 and F_5 were 15.6 % and 9.9 % respectively, higher compared to the recommended fertilizer rate (F_1). The higher yield of F_6 was mainly due to its greater grain mass plant^{-1} and 1000 seed mass. The KNO_3 sprayed during the seed filling stages (60 DAS) might had increased the availability of N and K to the plants. N is central in organic compounds formation in plants (Intanon, 2013). Besides the beneficial functions of nitrate nitrogen, the prevalence of K^+ in KNO_3, may had also improved grain filling and phytomass production, and the translocation of assimilates to reproductive apparatus (Ravikiran et al., 2012; Waraich et al., 2011). The relationship between leaf area plant^{-1} and grain mass plant^{-1} ($R^2 = 0.8276$) showed that, the high vegetative growth produced affected grain yield positively (Figure 2).

Our result are in line with those of other previous experiments as well. Soil application of 80 kg N ha^{-1} + foliar spray of 0.25 % KNO_3 + 0.203 % Ca $(NO_3)_2$, led to an increased soybean yield of 1.68 t ha^{-1}, about 10.7 % increase over the 1.5 t ha^{-1} produced by 80 kg N ha^{-1} + water spray (Raj & Mallick, 2017).

Again, Vekaria et al. (2013) reported that foliar application of 0.4 % KNO_3 ha^{-1} significantly increased soybean yield by 18.4 % when compared to water spray only. Intanon (2013) did mentioned that, the micronutrient (Fe, Zn and Cu) are important for carbohydrate formation. The presence of this element in F_5 could partly account for its high yield output.

Table 3: Influence of treatments on soybean yield components

Treatments	Pods plant^{-1}	Pod mass plant^{-1} (g)	Grain mass plant^{-1} (g)	1000 seeds mass (g)
Land Configurations				
FB	27.71	11.45^{b}	3.76^{b}	81.77^{b}
RF	28.19	11.87^{ab}	4.55^{a}	82.72^{ab}
BBF	29.68	12.32^{a}	5.09^{a}	85.56^{a}
CD @ 5%	NS	0.48	0.58	3.24
Fertilizers				
F_1	28.28	11.41^{bc}	4.23^{bcd}	79.84^{b}
F_2	26.85	10.26^{c}	3.75^{d}	76.52^{b}
F_3	28.51	12.44^{ab}	4.50^{bc}	82.86^{b}
F_4	27.65	10.95^{c}	4.01^{cd}	77.35^{b}
F_5	29.20	12.83^{ab}	4.92^{b}	84.95^{b}
F_6	30.65	13.40^{a}	5.36^{a}	96.56^{a}
CD @ 5 %	NS	1.75	0.74	9.04

Note: mean values with different superscript letter within each column denotes significance (p <0.05) between different groups. CD = critical difference between means; NS = non-significant (n = 15).

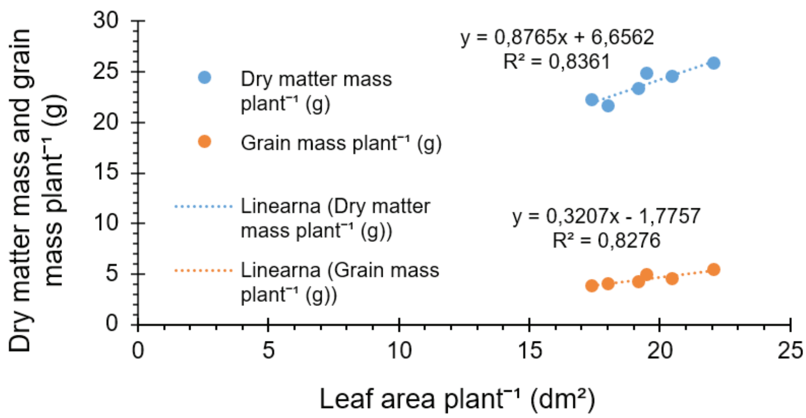

Figure 2: Regression analysis of leaf area plant^{-1} (dm^2) to total dry matter plant^{-1} and grain mass plant^{-1} (g)

The impact of boron (1 kg ha^{-1}) and molybdenum (0.5 kg ha^{-1}) on soybean yield had been demonstrated (Adkine et al., 2011); while the combination of NPK with 400 g Fe ha^{-1} and 20 g Mo ha^{-1} had also been reported by (Zahoor et al., 2013). In our work, land configuration had no significant effect on seed protein and oil content; likewise was the fertilizers on seed oil content, but numerically, the highest oil content of 19.65 % was obtained in F_5 and the lowest in F_2 (Figure 3). Seed protein content was significantly ($p < 0.05$) influenced by the fertilizers, with the highest (39.64 %, 39.38 %, 39.33 % and 39.18 %) realized in F_6, F_5, F_3, and F_4, respectively. The seed qualities observed in our study concur with those of (Kiran et al., 2008).

3.4 SOIL FERTILITY AFTER THE TRAIL

The different in situ soil moisture conservation techniques had no significant influence on soil fertility after the trial, though the best recordings were noticed in BBF (Table 5). The more soil water conserved in BBF, probably increased the crop residues added to the soil due to high vegetative growth (Selvarajua et al., 1999; Lal, 1995). The residual soil nitrogen (11.14 %), phosphorus (0.73 %) and potassium (1.85 %) contents were greatest in F_3 plots, probably due to the high NPK levels of this fertilizer formula. Phosphorous and potassium contents in particular, were significantly ($p < 0.05$) improved by F_3, when

Table 4: Influence of treatments on soybean yield, harvest index and rain water use efficiency.

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (HI)	RWUE (kg ha^{-1} mm^{-1})
Land Configurations					
FB	966.10^{b}	1913.00	2879.10	0.34	3.43^{b}
RF	1026.77^{ab}	1985.83	3012.60	0.34	3.64^{ab}
BBF	1058.97^{a}	2085.67	3144.63	0.34	3.76^{a}
CD @ 5 %	63.13	NS	NS	NS	0.22
Fertilizers					
F_1	979.03^{c}	1992.00^{abc}	2971.03^{bc}	0.33	3.48^{c}
F_2	916.37^{c}	1820.33^{c}	2736.70^{d}	0.34	3.25^{c}
F_3	1001.70^{b}	2019.33^{ab}	3021.03^{bc}	0.33	3.56^{bc}
F_4	959.73^{c}	1905.00^{bc}	2864.73^{cd}	0.34	3.41^{c}
F_5	1086.50^{ab}	2062.33^{ab}	3148.83^{ab}	0.34	3.86^{ab}
F_6	1160.33^{a}	2170.00^{a}	3330.33^{a}	0.35	4.12^{a}
CD @ 5 %	99.91	197.79	216.12	NS	0.35

Note: mean values with different superscript letter within each column denotes significance ($p < 0.05$) between different groups. CD = critical difference between means; NS = non-significant.

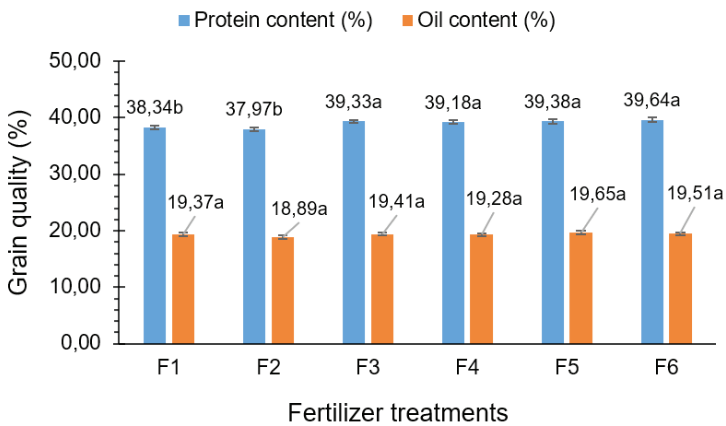

Figure 3: Influence of fertilizers on grain quality (n = 3)

compared to the other fertilizers. Generally, soil nitrogen and phosphorus content improve in all the plots, when compared to the levels before the trial. Our findings could be due to the *Rhizobium* culture (*Bradyrhizobium japonicum*) and phosphate solubilizing bacteria (PSB) treatment given to the seeds, as root nodules formations were generally observed on most roots. Also, the soil micronutrients; Fe, Zn, Cu, Mn and B contents were found the highest in F_5 with 8.75, 2.10, 0.60, 3.31 and 1.40 mg kg^{-1}, respectively. This could be due to the micronutrient spray given under this treatment. The lowest performance were observed in the F_2 plots.

4 CONCLUSION

Our result supports our hypothesis that (i) proper land configuration can promote soybean yield than flatbed; (ii) proper fertilization technique (foliar spray) can improve soybean yield and soil fertility. Our work has shown that BBF and RF can conserve more soil moisture for greater soybean growth and yield in vertisol soil. The application of F_6 also produced the highest soybean growth and yield. Therefore, for general soil improvement, the application of F_5 is recommended as it improved both the macro and micro soil nutrients elements, however for maximum yield, farmers in the

Table 5: Soil fertility after the trail

Treatments	N	P	K	Fe	Zn	Cu	Mn	B
			%			mg/kg		
Land Configurations		mg/kg						
FB	0.99	0.67	1.71	6.11	1.50	0.40	2.65	0.62
RF	0.98	0.66	1.71	6.23	1.53	0.39	2.66	0.58
BBF	0.99	0.69	1.73	6.43	1.57	0.42	2.68	0.62
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS
Fertilizers								
F_1	1.06^{b}	0.71^{ab}	1.79^{b}	5.68^{c}	1.50^{b}	0.34^{c}	2.50^{bc}	0.40^{d}
F_2	0.84^{c}	0.60^{d}	1.60^{d}	5.59^{c}	1.44^{b}	0.35^{c}	2.39^{c}	0.41^{d}
F_3	1.14^{a}	0.73^{a}	1.85^{a}	5.77^{c}	1.36^{b}	0.37^{b}	2.36^{c}	0.43^{cd}
F_4	0.89^{c}	0.67^{c}	1.71^{c}	6.16^{b}	1.43^{b}	0.39^{b}	2.88^{b}	0.48^{bc}
F_5	0.85^{c}	0.64^{cd}	1.61^{d}	8.75^{a}	2.10^{a}	0.60^{a}	3.31^{a}	1.40^{a}
F_6	1.13^{ab}	0.68^{bc}	1.74^{bc}	5.58^{c}	1.39^{b}	0.36^{b}	2.46^{c}	0.54^{b}
CD @ 5 %	0.07	0.04	0.05	0.29	0.22	0.03	0.38	0.06

Note: mean values with different superscript letter within each column denotes significance ($p < 0.05$) between different groups. CD = critical difference between means; NS = non-significant (n = 3).

Marathwada region of India are advise to adopt BBF + F_6 for soybean production.

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