The Pharma Innovation Journal 2021; 10(12): 1298-1302

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(12): 1298-1302

www.thepharmajournal.com
Received: 16-09-2021
Accepted: 30-10-2021

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# Effect of irrigation schedules and soil amendments on growth and nutrient content & uptake of soybean under Vertisols of South-Eastern Rajasthan

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**Abstract**
A field experiment was conducted during *kharif* season of 2020 at Agricultural Research Station, Ummedganj, Kota (Rajasthan) to evaluate the Effect of Irrigation Schedules and Soil Amendments on growth and nutrient content & uptake of Soybean under Vertisols of South-Eastern Rajasthan”. The experiment was laid out with twelve treatment combinations, which is consisting of three levels of irrigation schedules (0.6 (I1), 0.8 (I2) and 1.0 (I3) IW/CPE ratios) as a main plot treatments and four soil amendments (No soil amendments (S0), wheat straw (S1), mustard straw (S2) and Compost @ 5 t $ha^{-1}$) as sub plot treatments tested under strip plot design with three replications. The pooled data revealed that the increasing levels of irrigation schedules and different soil amendments increased the plant height, dry matter accumulation, number of nodules per plant as well as content and uptake of nitrogen, phosphorus and potassium in seed and straw. The significantly highest increase in growth parameter and nutrient content and uptake was observed under the treatment I3 (Irrigation schedules @ 1.0 IW/CPE ratio) with S3 (Compost @ 5 t $ha^{-1}$), Therefore, in this tract for soybean, the application of irrigation schedules @ 1.0 IW/CPE ratios with compost @ 5 t $ha^{-1}$ as a most profitable dose is being recommended for higher seed yield and net returns per hectare in Vertisols of South-Eastern Rajasthan.

**Keywords:** Soybean, irrigation schedules, soil amendments, yield attributes, nutrient content and uptake

## Introduction
Soybean [*Glycinemax* (L.) Merrill] is one of the most important legume and oil seed crop belongs to Family- Leguminosae or Fabaceae Subfamily Papilionaceae. It is originated from China and presently cultivated in different countries including USA, China, Brazil, Argentina and India etc. (Anonymous, 2020) [3]. Soybean also called as different names *viz*., wonder crop, yellow jewel, miracle bean, golden bean, meat of the field, gold of the soil, pearl of the orient. It is a nutritious food containing richest and cheapest source of vegetable protein (40 per cent), oil (20 per cent), well balanced in essential amino acids, rich in polyunsaturated fats specially Omega 6 and Omega 5 fatty acids, 6 to 7 present total minerals, 5 to 6 per cent crude fibre and 17 to 19 per cent carbohydrates (Chauhan and Joshi, 2005) [6]. Whereas, in India, soybean occupies an area of 11.33 million ha with production potential of 10.93 million metric tons and productivity of 0.96 metric tons $ha^{-1}$ during 2019-20 (Anonymous, 2021) [4] in India, soybean is now predominantly grown as rainfed crop in vertisols and associated soils with an average crop season rainfall of 900 mm (Mohanty *et al*., 2007) [21]. Vertisols (black soils) occupy 7% of the arable lands in the semi-arid tropical region of India and cover large areas under dry farming in central and southern India and also highly prone to sheet erosion. Surface runoff varies from 10 per cent to 40 per cent, and increases with increase in rainfall. Heavy texture and waterlogging make it difficult for early and rapid seedbed preparation (Pal and Deshpande, 1987) [25]. Vertisols often develop cracks during drying, which is a key feature that is taken as one of the criteria for classifying vertisols in soil taxonomy and Soil cracks increase water recharge *via* preferential flow in the rainy season. Further, the intricate network of cracks leads to the formation of potholes in vertisols. On the other hand, greater water loss from the surface and subsurface cracks through evaporation influence the number of wetting or drying cycles. Loss of soil moisture in rainfed regions can severely impact crop productivity and it can be altered or managed by land management practices and also by the addition of soil amendments or manures (Somasundaram *et al*., 2016) [28].

Organic amendments provide a good substrate for the growth of microorganisms and maintain a favourable nutritional balance and soil physical properties such as soil pH, available nutrients, labile C and total organic carbon and stocks and reducing the rate of crack formation in medium-deep black soils (Albiach *et al*., 2001) [2], on another hand organic soil amendments increased crop yield and there attributes by improving physiochemical property of the soil (Somasundaram *et al*., 2018) [29] One such strategy to maintain soil fertility for sustainable production of soybean is through judicious use of fertilizers coupled with organic resources that to achieve sustainability in production. (Bobde *et al*., 1998) [5]

A sustainable agricultural production system depends on good soil quality and amount of irrigation water and its application timing. The long term use of irrigation scheduling on soil properties and crop performance in fields with organic soil amendments incorporation had significant positive effect on soil bulk density (BD), saturated hydraulic conductivity ($K_{sat}$), water-stable aggregate, soil organic matter (SOM) and total nitrogen (Sun *et al.*, 2018) [29] and on another hand soil crack width and depth is positively influenced by different scheduling of irrigations (Mostafazadeh-Fard *et al*., 2010) [22].

## Materials And Methods

### Experimental site and soil characteristics

The experiment was undertaken in the field during the rainy season (july- October) of 2020 at the Agriculture Research Station, Ummedganj, Kota (Raj.) which is situated at South-Eastern part of Rajasthan at 75°.25' E longitude 25°.13' N latitude and an altitude of 258 meter above mean sea level. The soil of the college service area ranges from loamy to clay and categorized as Alluvial soils (recent group) to deep black soils with pH of 7.5, low in organic carbon (0.48%), available nitrogen (280.1 kg ha$^{-1}$), available $P_2O_5$ (15.7 kg ha$^{-1}$) and available $K_2O$ (356.0 kg ha$^{-1}$) and medium range of micronutrient. The region falls under agro-climatic zone V (Humid South eastern Plains) of Rajasthan.

### Treatments

The experiment was laid out with twelve treatment combinations, which is consisting of three levels of irrigation schedules (0.6 (I1), 0.8 (I2) and 1.0 (I3) IW/CPE ratios) as a main plot treatments and four soil amendments (No soil amendments (S0), wheat straw (S1), mustard straw (S2) and Compost @ 5 t ha$^{-1}$) as sub plot treatments tested under strip plot design with three replications. The recommended dose of fertilizer used for soybean was N: $P_2O_5$: $K_2O$ at the rate of 20: 40: 40 kg ha$^{-1}$. Nitrogen, phosphorus and potash were applied as basal as per treatment in the form of urea, DAP and MOP respectively. Soybean seeds were inoculated with the phosphate solubilizing bacterial (PSB) strain culture at 5 g kg$^{-1}$ seed and rhizobium as per treatment. The soil amendments (wheat straw (S1), mustard straw (S2) and Compost @ 5 t ha$^{-1}$) were applied fifteen days before sowing to the respective plots as per treatment.

### Variety and agronomic practices

Soybean variety JS20-34 is a medium duration, high yielding variety, widely cultivated in Hadoti region under South-Eastern part of Rajasthan. The crop was sown in the second week of July and harvested at second week of October in all the experimental years at 30 cm row spacing and 10 cm between plants. Hand weeding was done once at 40 days after sowing.

### Chemical analysis

Soil samples were collected, dried and ground for chemical analysis. Soil pH was determined by using a glass electrode pH meter (Jackson, 1973) [12] and organic carbon by wet oxidation method (Walkley and Black, 1934) [30]. The N content of the soil was determined by Kjeldahl method (Jackson, 1973) [12], available P by ascorbic acid and blue colour method (Watanabe and Olsen, 1954) [23] and available K by flame photometer (Jackson, 1973) [12]. Concentrated nitric acid was used for digestion of plant samples. Total P concentration was determined by Vanadomolybdate yellow colour method (Jackson, 1973) [12], K concentration by Flame photometer method (Jackson, 1973) [12]. Nutrient uptake was calculated by multiplying the N, P and K content of soybean grain and stover with their respective yield. The total nutrient uptake was obtained by summation of the nutrient uptake of grain and straw.

## Result and Discussion

### Plant height

Plant height was significantly influenced by the increasing level of irrigation schedules with different soil amendments. Plant height produced by I3 (37.3 cm) at 60 DAS and (48.3 cm) on harvest stage was significantly higher than that of all other treatments and the lowest plant height were in the I1 (31.14 cm and 41.0 cm) at 60 DAS and harvest. The soil amendments positively affected plant height at 60 DAS and it's varied from 31.8 cm under no soil amendments (S0) to 37.1 cm in S3. The application of compost @ 5 t ha$^{-1}$ (S3) significantly promoted highest plant height (37.1 cm) as compared to S0 (31.8 cm). Similarly, plant height (35.70 cm) was also significantly at par with S1 compared to S2. At harvest stage, the plant height significantly increased with application of different soil amendments. The application of compost @ 5 t ha$^{-1}$ (S3) significantly promoted highest plant height (48.4 cm) as compared to S0 (38.4 cm). Similarly, plant height in (46.0 cm) was also significantly at par with S1 compared to S2 (Table 1). It was clearly indicate that increasing levels of irrigation schedules with use soil amendments which increased the availability of nutrients considerably resulting in a positive effect on growth parameters. These findings are in accordance with the results of Kazi *et al.* (2002) [13] and Devi *et al*. (2013) [10] who had observed maximum plant height, branches and pod per plant, seed index, seed yield and oil content percentage in soybean due to the application of well irrigation scheduling and compost. Similar findings were reported (Yagoub *et al*., 2012; Khaim *et al*., 2013; Aher *et al.*, 2015 in soybean) [31, 14, 1].

### Dry matter accumulation (meter$^{-1}$ row length)

Data pertaining dry matter accumulation in table 1 found that the application of irrigation with I3 (1.0 IW/CPE ratio) accumulated maximum dry matter at 60 DAS (82.53 g plant$^{-1}$) and at harvest (108.11 g plant$^{-1}$) significantly higher at all the growth stages, compared to I1 and I2, representing an increment of 3.90 and 11.5 at 60 DAS, 1.21 and 9.60 per cent at harvest increases, respectively. However, rapid improvement in dry matter accumulation was noticed between vegetative and flowering stage of soybean. As well as maximum accumulated dry matter at 60 DAS (83.5 g plant$^{-1}$) and at harvest (107.08 g plant$^{-1}$) found significantly with application of S3 (compost@ 5 t ha$^{-1}$). The significantly maximum dry matter accumulated at all growth stage was recorded under the treatment S3 and the minimum under S0 (No soil amendments). However, the increase was significant up to S1 which was also found to be statistically at par with S2. The number of maximum dry matter accumulated per plant was recorded as (6.29, 8.46 & 14.63 at 60 DAS) and (3.72, 7.46 & 10.4 at harvest) per cent with application of S2, S1 and S3, respectively as compared to S0 (No soil amendment) (Table 1). Soil amendments may affect the release of nutrients to plants directly through the nutrients present in them or indirectly by their effect on the cation-exchange capacity. Thus balanced nutrition under favorable environment might have helped in production of new tissues and development of new shoots. Soil amendments also increased the activity of soil microorganism like plant growth promoting bacteria it's helpful in development of plant root. This might be due to overall improvement in vigor and crop growth due to adequate supply of nutrients during different growth stage considered important in promoting rapid vegetative growth and biomass. These results are in agreement with those of Khurshid *et al*. (2006) [16], Singer *et al,* (2008) [27], Yagoub *et al.* (2012) [31], Khaim *et al*. (2013) [14] Devi *et al*. (2013) [10], Mohammed *et al*. (2019) [20] and Dahri *et al*. (2018) [7].

**Nodulation**

The number of nodules per plant was influenced significantly by the different irrigation schedules and soil amendments. The number of nodule per plant ranges from 11.67 to 43.00. The maximum nodules per plant (79.4 & 82.3) were found in the irrigation at I1 and with the application of compost at the rate of 5 t ha$^{-1}$. But irrigation scheduling significantly not affected nodules per plant at 45 DAS (Table 1). The ideal moisture in soil with no limitation increase both mass and distributions of roots in the upper soil profile and thus nutrients are taken up by exploring a greater volume of soil. Due to these, the physiological processes are activated and plant growth including plant heights, dry matter and nodules increase with increased level of irrigation and soil amendments. The results are in conformity with the findings of Kazi *et al.* (2002) [13] Padmalatha *et al*. (2002) [24], Maheswari *et al*. 2007 [18], Mansur *et al*. (2010) [19] and Rathore *et al*. (2020) [26].

**Nutrient content and uptake**

The application of increasing levels of irrigation schedules and soil amendments significantly increased the nutrient content and uptake by seed and straw of soybean. The maximum nutrient content (N 6.49 and 1.63 per cent, P 0.65 and 0.31 per cent and K 1.41 and 3.85 per cent) and uptake (N 97.0 & 24.4 kg ha$^{-1}$, P 9.75 & 4.60 kg ha$^{-1}$ and K 21.03 & 57.33 kg ha$^{-1}$) in seed and straw was recorded under the treatment I3 (1.0 IW/CPE ratios) as compared to I1 (0.6 IW/CPE ratios), respectively. The increase in nutrient uptake due to application of irrigations at 1.0 IW/CPE ratios were in order of N 4.77 & 6.74 per cent, P 20.0 & 29.0 per cent and K 7.09 & 7.27 per cent in seed and straw of soybean, respectively as compared to 0.6 IW/CPE ratios (I1) (Table 2 & 3). It is might be due to adequate supply of irrigation during different early time periods considered important in promoting rapid vegetative growth and biomass. The results of present investigation are in line with those of growth parameters of soybean, who obtained increased yield attributes, grain, Stover and biological yield with the applied of irrigation schedules up to three levels and better vegetative growth was ultimately associated with higher yield attributing characters due to increased absorption of minerals, nutrients under adequate available soil moisture. These results are in close conformity with the findings of Maheswari *et al*. (2007) [18], Demirtas *et al.* (2010) [9], Deewan *et al*. (2015) [8] and Kumbhar *et al*. (2015) [17].

The application of soil amendments significantly increased the nutrient content and uptake by seed and straw of soybean. The higher nutrient content (6.62 and 1.67 per cent, P 0.61 & 0.30 per cent and K 1.40 & 3.77 per cent) and uptake (97.9 & 24.7 kg ha$^{-1}$, P 9.03 & 4.47 kg ha$^{-1}$ and K 20.7 & 55.7 kg ha$^{-1}$) in seed and straw was obtained under the treatment S3 (compost @ 5 t ha$^{-1}$) and the minimum under S0 (No soil amendments), respectively (Table 2). The increase in nutrient uptake due to application of 5 t compost ha$^{-1}$ were in order of N 28.4 & 31.0 per cent, P 32.3 & 44.3 per cent and K 25.5 & 24.4 per cent in seed and straw of soybean, respectively as compared to S0 (No soil amendments). However, the nutrient uptake of N, P and K in seed and straw was increased significantly up to S2 which was found to be statistically at par with S2 (Table 2 & 3). The positive influence of soil amendments was due to adequate supply of nutrients in root zone and plant system. The increased availability of these nutrients in the root zone coupled with increased metabolic activity at cellular levels might have synthesized more nutrients and their accumulation in various plant parts (Yaseen *et al*., 2014) [32]. The increased uptake of nitrogen, phosphorus and potassium content in seed and straw seems to be due to the fact that uptake of nutrient is a product of biomass and nutrient content. The nutrient accumulation in plant is dependent on dry matter accumulation in plant and concentration of nutrient at cellular level. It is evident form significant correlation between dry matter accumulation and uptake of nutrients. The results obtained in the present investigation are in close conformity with those of Ding *et al.* (2020) [11]. The increase in content of well irrigation schedules with application of soil amendments might be due to increased availability of native micronutrient cations. Thus, positive effects of soil amendments on nutrient availability and their extraction due to increase activity of roots ultimately improved the nutrient status of the plant parts (Khan *et al*., 2020) [15].

**Table 1:** Effect of irrigation schedules and soil amendments on growth parameter of soybean

| Treatment | Plant height (cm) | | Dry matter g plant$^{-1}$ | | No. of nodules plant$^{-1}$ |
|---|---|---|---|---|---|
| | 60 DAS | At harvest | At 45 DAS | At harvest | At 45 DAS |
| **Irrigation schedules (W/CPE ratios)** | | | | | |
| I1 0.6 | 31.14 | 40.94 | 73.02 | 97.73 | 77.07 |
| I2 0.8 | 34.99 | 42.14 | 75.99 | 98.93 | 77.13 |
| I3 1.0 | 37.30 | 48.29 | 82.53 | 108.11 | 79.41 |
| S.Em+ | 0.56 | 1.17 | 0.73 | 1.50 | 1.20 |
| CD (P=0.05) | 2.19 | 4.61 | 2.87 | 5.88 | NS |

| | | | | | |
|---|---|---|---|---|---|
| **Soil Amendments (5 tones ha$^{-1}$)** | | | | | |
| S0 No soil amendments | 31.79 | 38.34 | 71.28 | 95.94 | 74.01 |
| S1 wheat straw | 35.70 | 45.98 | 77.87 | 103.68 | 78.85 |
| S2 mustard straw | 33.30 | 42.44 | 76.07 | 99.65 | 76.41 |
| S3 compost | 37.11 | 48.39 | 83.50 | 107.08 | 82.22 |
| S.Em+ | 0.17 | 1.63 | 0.58 | 0.39 | 1.06 |
| CD (P=0.05) | 0.60 | 38.34 | 1.99 | 1.37 | 3.66 |

**Table 2:** Effect of irrigation schedules and soil amendments on NPK content in soybean

| Treatments | N content (%) | | P content (%) | | K content (%) | |
|---|---|---|---|---|---|---|
| | Grain | Grain | Grain | Grain | 0-15 cm | 15-30 cm |
| **Irrigation schedules (IW/CPE ratios)** | | | | | | |
| I1 0.6 | 6.20 | 1.52 | 0.52 | 0.22 | 1.31 | 3.57 |
| I2 0.8 | 6.18 | 1.52 | 0.53 | 0.24 | 1.36 | 3.68 |
| I3 1.0 | 6.49 | 1.63 | 0.65 | 0.31 | 1.41 | 3.85 |
| S.Em+ | 0.06 | 0.02 | 0.004 | 0.004 | 0.01 | 0.01 |
| CD (P=0.05) | 0.24 | 0.07 | 0.018 | 0.015 | 0.02 | 0.05 |
| **Soil Amendments (5 tones ha$^{-1}$)** | | | | | | |
| S0 No amendment | 6.02 | 1.46 | 0.52 | 0.21 | 1.32 | 3.60 |
| S1 wheat straw | 6.33 | 1.59 | 0.59 | 0.27 | 1.37 | 3.73 |
| S2 mustard straw | 6.20 | 1.52 | 0.55 | 0.24 | 1.34 | 3.68 |
| S3 compost | 6.62 | 1.67 | 0.61 | 0.30 | 1.40 | 3.77 |
| S.Em+ | 0.07 | 0.01 | 0.003 | 0.002 | 0.005 | 0.01 |
| CD (P=0.05) | 0.24 | 0.04 | 0.011 | 0.008 | 0.02 | 0.05 |

**Table 3:** Effect of irrigation schedules and soil amendments on NPK uptake in soybean

| Treatments | N uptake (kg ha$^{-1}$) | | P uptake (kg ha$^{-1}$) | | K uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|
| | Grain | Grain | Grain | Grain | 0-15 cm | 15-30 cm |
| **Irrigation schedules (IW/CPE ratios)** | | | | | | |
| I1 0.6 | 78.50 | 19.41 | 6.42 | 2.74 | 16.15 | 44.05 |
| I2 0.8 | 76.66 | 18.82 | 6.73 | 3.07 | 17.23 | 46.68 |
| I3 1.0 | 97.03 | 24.41 | 9.75 | 4.60 | 21.03 | 57.33 |
| S.Em+ | 2.23 | 0.56 | 0.16 | 0.08 | 0.33 | 0.84 |
| CD (P=0.05) | 8.75 | 2.20 | 0.63 | 0.30 | 1.28 | 3.28 |
| **Soil Amendments (5 tones ha$^{-1}$)** | | | | | | |
| S0 No amendment | 70.12 | 17.03 | 6.11 | 2.49 | 15.38 | 42.09 |
| S1 wheat straw | 87.55 | 21.97 | 8.18 | 3.82 | 19.02 | 51.65 |
| S2 mustard straw | 80.71 | 19.83 | 7.21 | 3.11 | 17.48 | 48.02 |
| S3 compost | 97.88 | 24.69 | 9.03 | 4.47 | 20.66 | 55.66 |
| S.Em+ | 2.92 | 0.59 | 0.24 | 0.12 | 0.54 | 1.51 |
| CD (P=0.05) | 10.11 | 2.03 | 0.83 | 0.43 | 1.87 | 5.22 |

## Conclusion

Based on the above findings it may be inferred that substantial improvement in plant height, dry matter per plant, number of nodules per plant and nutrient content & uptake of N, P and K in seed and straw could be obtained with the application of irrigation at 1.0 IW/CPE ratios and compost (@ 5 t ha$^{-1}$). Therefore, in this tract for soybean variety JS20-34, the application of irrigation at 1.0 IW/CPE ratios and compost @ 5 t ha$^{-1}$ as a most profitable dose is being recommended for higher growth and nutrients content & uptake per hectare in Vertisols of south-eastern Rajasthan.

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