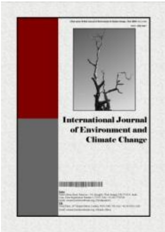

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Effect of Different Kinds of Water on Growth, Yield and Water Use Efficiency of Soybean

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment conducted at International Crops Research Institutefor the Semi-Arid Tropics (ICRISAT), Patancheru, India to study the effect of different quality of water on growth, yield and water use efficiency of soybean during rabi 2015-16. The experiment was laid out in randomized block design (RBD) and replicated fivetimes with three treatments i.e. untreated wastewater, treated wastewater and fresh water. The result of the present study indicate that untreated wastewater affect plant height, leaf area index, dry matter production, number of pod per plant, test weight, seed yield and straw yield significantly. Highest seed yield of soybean was observed in untreated wastewater (22.20 q ha^{-1}) in relation to wastewater and freshwater. Higher value of growth attributes and yield attributes were found in untreated wastewater. Highest water use efficiency of soybean was also recorded in untreated wastewater treatment. This study, it concluded untreated wastewater increased growth attributes, yield attributes and yield and also

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water use efficiency due to presence of enough amount of nutrient in untreated wastewater and less amount of heavy metal that help to achieve maximum seed yield and water use efficiency in soybean.

Keywords: Kind of water irrigation; water used efficiency; yield and soybean.

1. INTRODUCTION

Soybean (*Glycine max* (L.) is the leading oilseed crop in the world with an area of 145 m ha. In India too, it is the most important oilseed crop with an area of10.6 mha and a production of 10.98 m tons with an average productivity of 1017 kgha [1]. Soybean is often termed as “miracle crop” because of itsnutritional value and versatile applications. Some of the major limiting factors for low productivity of soybean are limiting moisture conditions, as this is mostly grownunder rain fed conditions during *kharif.* The imbalanced and inadequate fertilizationis also found to be one of the major limiting factors for its poor yield.Ensuring global food security for the ever growing population that willcross nine billion by 2050 and reducing poverty is a challenging task. Increasedfood production has to come from the available and limited water and landresources which are finite. Neither the quantity of available water nor land hasincreased since 1950s, but the availability of water and land per capita has declined significantly due to increase in global human population. As demand for fresh water intensifies,wastewater is frequently being seen as a valuable resource and is an importantalternative source of water for irrigation [2].

Waste water becomes an alternative source of irrigating the soybean crop to achieve maximum yield. Waste water can improve the soil fertility as well as decrease use of chemical fertilizer. Wastewater from different sources not only provides water but also containsconsiderable amount of organic matter and plant nutrients (N, P, K, Ca, S, Cu, Mn and Zn) and has been reported to increase the crop yield [3,4]. By considering this information, the present experiment was conducted to study the effect of different quality of wastewater on growth, yield and water use efficiency of soybean.

2. MATERIALS AND METHODS

The present investigation was carried out at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India under the project of Water4Crops -“Integrating bio-treated wastewater reuse and valorization with enhanced water useefficiency to support the Green Economy in Europe and India to assess the effect of wastewater irrigation on crop and water use efficiency during *rabi*2015-16. The experiment was laid out in randomized block design (RBD) and replicated five times with three treatments. The treatments based on irrigation water quality *i.e.* fresh water (FW) from open well, treated wastewater (TWW) from collection pond which is treated wastewater through constructed wetlands and untreated wastewater (UTWW) from municipal wastewater BHEL residential colony. The experimental field was ploughed with bullock drawn disc plough followed by two ploughings with cultivator and the clods were broken. The field was uniformly leveled, broad bed and furrows were prepared and divided into plots.JS-335 variety of soybean was used in this experiment. Sowing were carried out though bullock drown seed drill at a depth of 5 cm by adopting an inter-row spacing of 30cm for Soybean and plant to plant distance of 10 cm to achieve desired plant population ha^{-1}. The recommended dose of Soybean was 30 kg N + 60 P_2O_5 + 0 kg K_2O ha^{-1}. Full dose of nitrogen, phosphorus and potassium were applied as a basal dose for soybean. Plant height was recorded at 30, 60, 90 DAS and at harvest from the ground level to the tip of the main shoot and average plant height were recorded in cm. The leaf area index was measured at 30, 60, 90 DAS and at harvestfor soybean with LI 3100Leaf Area Meter (LI-COR, INC. Linocoln, Nebraska, USA). At each sampling three plants were harvested and green leaves were separated and were inserted into Leaf Area Meter. For dry matter measurement, three plants were uprooted from the destructive sampling area at 30, 60and 90 DAS and at Harvest for soybean were sun dried initially and subsequently dried in hot air oven at 60 ^{0}C till constant weight was obtained. These weights were recorded, averaged and expressed in kg ha^{-1}. WUE (kg m^{-3}) was represented as grain yield (kg ha^{-1}) per unit of ETa (mm)

WUE = GY/ ETa where GY is grain yield (kg ha^{-1}) and ETa is total evapotranspiration (mm) calculated from Equation (1).

Evapotranspiration (ETa, mm) was calculated during the growing season using the soil water balance equation:

$$ETa = I + P + Cr - Rf - Dp \pm \Delta S \quad (1)$$

where I (mm) was irrigation, P (mm) was precipitation, Cr (mm) was capillary rise, Dp (mm) was percolation, Rf (mm) was runoff, and ΔS (mm) was the change in soil water storage.

LAI was calculated as the ratio of LA (m^2) to land area (m^2) using the following formula:

$$LAI = LA/\text{Ground area} \quad (2)$$

Soil samples were collected prior to layout of the experiment at 0-30 cm depth. The present experimental soil was sandy loam, dark reddish brown colour, low in organic carbon (0.26 %), slight alkaline in reaction (7.7), non-saline (0.15 dS m^{-1}), low in available nitrogen (238 Kg ha^{-1}), medium in availablephosphorus (19 Kg ha^{-1}), medium in available potassium (264 Kg ha^{-1}) and low in CEC (13.8 C mol (p+) kg^{-1}). Secondary nutrient content in experimental soil was2048 ppm of Ca, 364 ppm of Mg and 3.9 ppm of S. Micronutrient in sandy loamsoil of ICRISAT were in the order of Fe>B>Mn>Cu>Zn. Heavy metal content inexperimental soil was below the permissible limit of soil in the order of Cr>Pd>As>Cd. The irrigated water was analyzed toascertain the quality of water by following standard methods [5] (Table 1). The data obtained on the different growth and yield components and yield were analyzed statistically as per the procedure given by Gomez and Gomez [6].

Table 1. Water quality analysis data used for irrigation

Sr. No.	Parameters	Fresh water	Treated waste water	Untreated waste water
1	pH	6.6	7.2	7.8
2	EC	1.1	1.3	1.7
3	Carbonate (me/L)	BDL	BDL	BDL
4	Bicarbonate (me/L)	52.7	91.2	139.8
5	Chloride (mg/L)	83	138	219
6	Sulphate	7.02	11.84	20.55
7	Calcium (me/L)	34	63	91
8	Magnesium (me/L)	18	27	47
9	Sodium (mg/L)	21	42	72
10	Phosphorus (mg/L)	BDL	0.86	2.18
11	Potassium (mg/L)	2.48	17.82	22.67
12	Ammonical-Nitrogen (mg/L)	1.72	21.44	57.26
13	Nitrate-Nitrogen (mg/L)	0.67	4.10	4.38
14	Chemical Oxygen Demand (COD)	55.6	186.1	306.2
15	Biochemical Oxygen Demand (BOD)	21.2	114.9	137.3
16	Residual Sodium Carbonate (RSC)	0.7	1.2	1.8
17	Sodium Adsorption Ratio (SAR)	4.11	6.27	8.66
18	Boron	0.05	0.08	0.08
19	Cadmium	BDL	BDL	BDL
20	Chromium	BDL	BDL	BDL
21	Cobalt	BDL	BDL	BDL
22	Arsenic	0.01	0.01	0.01
23	Lead	BDL	BDL	BDL
24	Copper (µg lit -1)	0.01	0.02	0.05
25	Manganese	0.01	0.04	0.05
26	Iron	0.08	0.1	0.3
27	Zinc	1.2	2.6	4.1
28	Nickel	BDL	BDL	BDL

3. RESULTS AND DISCUSSION

3.1 Plant Height

Plant height of soybean at different stages (at 60, 90 DAS and at Harvest) except at 30 DAS were significantly increased with application of waste water (Table 2). According to Table 2 maximum plant height of soybean at different stages was observed in untreated wastewater followed by treated waste water and fresh water. Plant height of soybean in untreated wastewater treatment at 30, 60, 90 DAS and at harvest were 23.94 cm, 47.56 cm, 53.20 cm, and 56.12 cm respectively (Table 2). Plant height of soybean was increase significantly after 30 DAS to the harvest due to the more concentration of available in untreated wastewater and also the more uptake of nutrient from untreated wastewater treatment which is responsible for cell division, elongation and auxin formation, thus increase the plantheight. The result of present study agrees with Shinde et al. [7] who reveal that plantheight of soybean was significantly increases by the nutrient content in soil and uptake inplant. Similar results were obtained by Szögi et al. [8]. Frigo et al. [9] found non-significant difference in plant height of soybean at different growth stages with wastewater application. Chateaubriand [10] reported that plant height of corn by swine wastewater was increased by 19%, compared to fresh water.

3.2 Leaf Area Index

The leaf area index (LAI) increased at a slower rate up to 30 DAS and thereafter it increased linearly with the ontogeny of the plant reaching a peak value at 60 and 90 DAS but thereafter it decreased precipitously towards maturity due to senescence of leaves (Fig. 1). Significant effect of different treatments on LAI was observed from 30 DAS and it was sustained till the harvest of the crop. At all the stages of crop growth the LAI recorded in all the UTWW irrigation treatments were significantly superior over thetreatments irrigated with TWW and followed by FW irrigation treatment. LAI of soybean in untreated wastewater at 30, 60, and 90 DAS were 0.87, 5.36, and 9.66 respectively. At harvest, the LAI followed similar pattern as that of LAI at 90 DAS but the LAI reduced at maturity due to the senescence of leaves (Fig. 1). Highest LAI was recorded in untreated wastewater irrigation treatment (6.42) followed by treated wastewater (6.82) while lowest LAI was observed in fresh water irrigation treatment (7.88). Leaf area index was increased by the application of untreated waste waterirrigation treatment. Leaf area index increased with increase nitrogen, phosphorus,potassium and micronutrient content in leaf. These nutrients are responsible for increasing number of leaves in soybean. Similar results were obtained by Shinde et al. [7]. El-Maghraby and Gomaa [11] reported that sewage water application increased number of green leaves and leaf area perplants or it may be increase both of macro and micronutrients elements in soil, which isessential for the plant growth and photosynthetic pigments. Irrigation of soybean with swine wastewater, LAI of soybean was increased after 45 DAS [9]. Szögi et al. [8] reported higher value of LAI of soybean with swine wastewater than fresh water.

3.3 Dry Matter Production

The observations recorded on dry matter production of Soybean at 30, 60, 90DAS and at harvest stages are presented in Fig.2. The dry matter production increases throughout the crop growth period and followed sigmoid pattern. At all the stages of crop growth, the highest dry matter production was recorded at untreated wastewater (UTWW) treatment followed by treated wastewater (TWW) and lowest in fresh water (FW) irrigation treatment in both the years. At 30 DAS, the highest dry matter production was recorded 3.60 g plant^{-1} in UTWW treatment followed by TWW were recorded 3.20 g plant^{-1}. The lowest dry matter was recorded in FW treatment *i.e.*3.03 g plant^{-1}. Similar trends were followed at 60 and 90 DAS with significant difference as per Fig. 2. Highest dry matter production at 60 and 90 DAS *i.e.* 10.99 g plant^{-1} and 52.01 g plant^{-1}was recorded in untreated wastewater irrigation treatment followed by treated wastewater while lowest dry matter production at 60 and 90 DAS *i.e.* 8.63 g plant^{-1}and 38.18 g plant^{-1}was recorded in fresh water irrigation treatment (Fig.2). At harvest, the highest dry matter was 60.05 g plant^{-1}in UTWW irrigationtreatment and lowest was 46.55 g plant^{-1}in FW irrigation treatment. Plant height and leaf area index are directly responsible for dry matter production in soybean. Highest dry matter production was observed by the application of untreatedwastewater might be due to more supply of nutrient to plant which is responsible for more photosynthetic activities and directly involved in metabolic process. Similar result was obtained by Shinde et al. [7]. Szögi et al. [8] who reported that dry matter production in soybean was increases with wastewater application but in limited quantity. Dry matter production rate was decreases with increase of wastewater application rate [8]. Frigo et al. [9] reported higher value of dry mass in soybean with swine wastewater in relation to the fresh water.

Table 2. Effect of different irrigation water treatments on plant height (cm) of Soybean

Treatment	30 DAS	60 DAS	90 DAS	At harvest
FW	21.58	44.92	49.24	52.18
TWW	22.66	46.60	51.48	54.06
UTWW	23.94	47.56	53.20	56.12
SE.m (±)	0.24	0.48	0.32	0.45
CD (P=0.05)	0.69	1.41	0.95	1.33

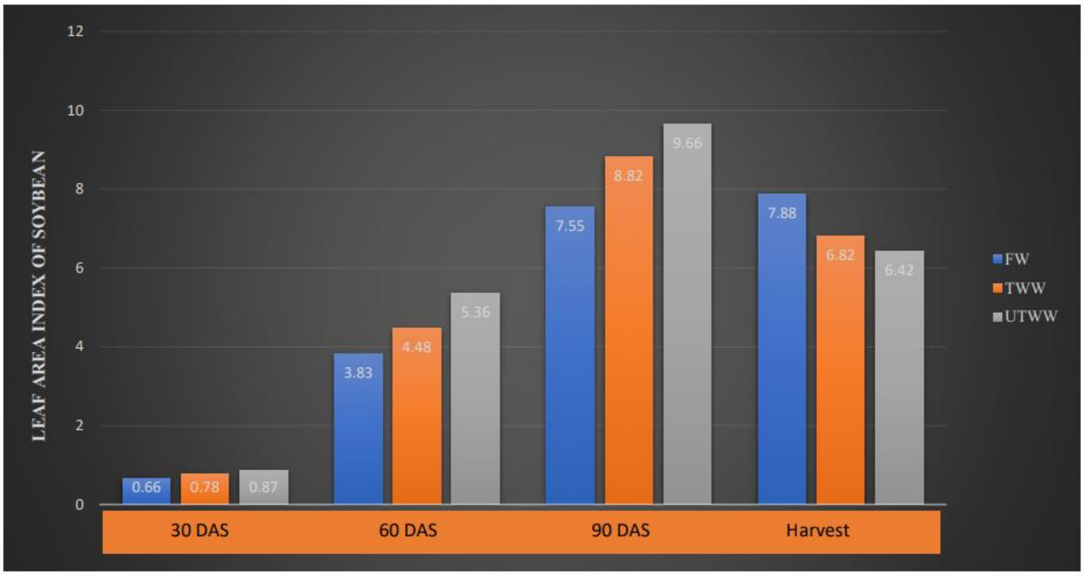

Fig. 1. Effect of different kind of irrigation water on leaf area index of soybean

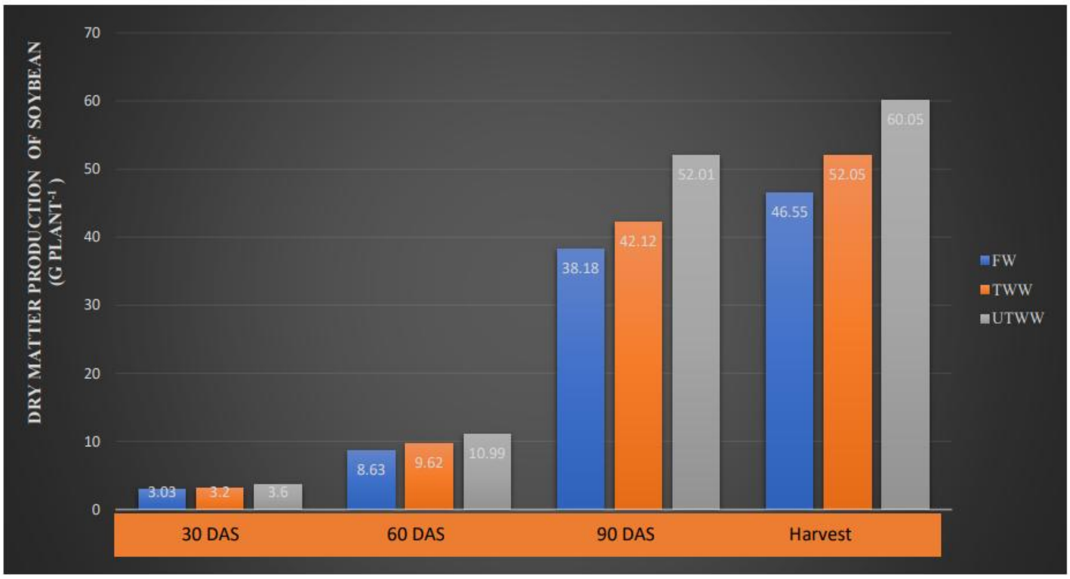

Fig. 2. Effect of different kind of irrigation water on dry matter production of soybean (g plant^{-1})

3.4 Yield and Yield Attributes

3.4.1 Number of pods per plant

Number of pods per plant was significantly affected by the application of different quality irrigation water is presented in Table 3. Highest number of pods per plant recorded in the untreated wastewater (UTWW) irrigation treatment *i.e.* 76.60 and lowest in the fresh water (FW) irrigation treatment 61.00 followed by the treated wastewater (TWW) was 69.40 (Table 3). Number of pod per plant was increases due to more supply of essential nutrient by the application of untreated wastewater (UTWW) irrigation treatment. Micronutrients also play a major role in flower formation and poddevelopment. Pod number per plant was also increases by the application of untreated wastewater (UTWW) irrigation might be due to lower concentration of heavy metal in wastewater. Singh and Agrawal [12] reported that irrigation of mung bean with sewage sludge was improve the soil fertility status that increases number of pod in mung bean and Shinde et al. [7] reported that number of pod per plant was increase with presence of enough amount of major and micronutrient in soil that help the plant at reproductive stage for fertilization.

3.4.2 Test weight (g)

Test weight of soybean was non-significantly influenced by the different water irrigation treatment, as the water qualities not affect the size and weight of seeds with an average test weight of 14.10 g (Table 3). Test weight is a genetic character however, different treatment may not affect. Test weight of soybean was non-significantly influenced by the different water irrigation treatment. Slight variation of test weight was observed by the different water irrigation treatment. Highest test weight of soybean was increased due to more utilization ofmacronutrient and micronutrient in protein and carbohydrate formation which is esponsible for production of healthy seed. The result was in accordance with Sahar et al. [13] who reported higher test weight in wheat with application of textile waste water compared to control. Test weight of maize was not increase significantly but it was increase only with increase of nitrogen or phosphorus dosein double than initial value [14] and Mousavi and Shahsavari [15] reported higher test value in maize with application municipal wastewater due to presence of nutrient in double quantity than fresh water.

3.4.3 Seed yield (kg ha^{-1})

Table 3 shows that seed yield of Soybean was significantly influenced by different irrigation water qualities. The untreated wastewater (UTWW) recorded higher seed yield of 22.20 q ha^{-1}and lower seed yield of 17.28 q ha^{-1}in fresh water (FW) irrigation treatment followed by treated wastewater (TWW) seed yield of 20.12 ha^{-1}(Table 5). . Mostly grain yield depend on the yield components *viz.,* number of pod and test weight that was highest recorded in untreated wastewater due to more availability and essential nutrient in adequate amount at flowering and pod development stages. The result was in accordance with Szögi et al. [8] who reported higher soybean yield with swine waste water due to more nutrient export by plant from soil in relation to fresh water. Hamid et al. [16] proved that wastewaters not only effective source of water but the nutrients also and enhanced growth and photosynthetic capacity and thereby yield of the plants. Maximum grain of yield was 8488 kg/ha-1 with application of treated municipal wastewater due to presence of rich amount of nutrients such as nitrogen, phosphorus, potassium, calcium, zinc and iron in wastewater [15].

3.4.4 Straw yield (kg ha^{-1})

Straw yield of Soybean showed similar trend as observed in seed yield. Scheduling of irrigation with UTWW registered highest straw yield over TWW and FW treatments (Table 3). Significantly highest straw yield of 28.92 q ha^{-1}was recorded in the treatment of UTWW irrigation and was statistically on par withTWW irrigation treatment recorded straw yield of 27.68 q ha^{-1}compare with FWtreatment. The lowest straw yield of 26.08 q ha^{-1} was recorded with FW irrigation treatment. Straw yield of soybean was increases with increasing plant height, leaf area indexand dry matter production. These growth parameter *viz*., plant height, leaf area indexand dry matter production was increased by the application of untreated wastewater(UTWW) irrigation due to the improvement of physical, chemical and biologicalproperties of soil which is responsible for proper growth development and also due to more uptake of essential nutrient. The result of present study agrees with shinde et al. [7] who reported that straw yield of soybean increased due to more uptake of essential nutrient. Similar result was also obtained by Singh et al. [17]. Sahar et al. [13] reported that straw yield of wheat was increases up to 77 % with used of

Table 3. Effect of different irrigation water treatments on No. of pods per plant,test weight (g), seed yield (qha^{-1}), straw yield (qha^{-1}), harvest index (%)and water use efficiency (WUE) (kg ha^{-1}mm^{-1}) of Soybean

Treatment	No. of pods per plant	Test weight (g)	Seed Yield (qha^{-1})	Straw Yield (qha^{-1})	Harvest Index (%)	WUE (kg ha^{-1} mm^{-1})
FW	61.00	13.82	17.28	26.08	44.29	4.32
TWW	69.40	14.10	20.12	27.68	44.42	5.06
UTWW	76.60	14.18	22.20	28.92	44.94	5.59
SE.m (±)	0.90	0.21	0.70	0.35	0.34	0.31
CD (P=0.05)	2.64	NS	2.04	1.03	NS	0.91

textile wastewater in comparison of control due to positive effect of available nutrient in present in wastewater.

3.4.5 Harvest Index (HI)

The water quality irrigation treatment results show non-significant difference on harvest index shown in Table 3. Highest harvest index was calculated in untreated wastewater irrigation treatment (44.29 %) followed by treated wastewater (44.42 %) while lowest harvest index was calculated in fresh water irrigation treatment (44.94 %). Harvest index was depend on the grain yield which has affected by theapplication of untreated wastewater. Similar result was also obtained by Sahar et al. *[13]* in wheat and Tadesse et al. [18].

3.4.6 Water use efficiency (WUE)

The untreated wastewater (UTWW) irrigation treatment show higher WUE of 5.59 kg ha^{-1}mm^{-1}followed by thetreated wastewater (TWW) of 5.06 kg ha^{-1}mm^{-1}and lowest in the fresh water (FW)irrigation treatment 4.32 kg ha^{-1}mm^{-1} (Table 3). Water use efficiency of wastewater was similar to fresh water. In present study, WUF of soybean was more with untreated wastewater followed by treated waste water and then fresh water. In the soil solution contained enough amounts of both macro and micronutrient responsible for more export of nutrient by plant and also responsible for higher uptake of water in plant. In this study, same situation observed with untreated wastewater. In untreated wastewater contained enough amounts of macro and micronutrient which shown synergetic effect with water and help for more uptake of water in plant in relation to treated wastewater and fresh water. Al- Khamisi et al. [19] reported higher water use efficiency in waste water treatment in relation to fresh water. Balkhair et al. [20] in vegetables and Chikkaswamy et al. [21] inmulberry reported higher water use efficiency in wastewater with furrow irrigation method than fresh water [22-24].

4. CONCLUSION

All response variables showed improvement due to untreated water treatment except LAI and test weight.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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