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Research Paper

Effect of fertigation of primary treated biomethanated spentwash along with nitrogen levels on soil micronutrient, heavy metal status, uptake, economics and yield of soybean (*Glycine max*)–wheat *(Triticum aestivum)* cropping sequence on Inceptisol

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ABSTRACT

The field experiment was carried out during the third (2009–10) and fourth years (2010–11), which was initiated in 2007–08 at Rahuri, to study the effect of fertigation of primary treated biomethanated spentwash (PBSW) on micronutrient, heavy metal status of soil and uptake of soybean [*Glycine max* (L.) Merr.] and wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.], when grown in a sequence. The treatments comprised recommended dose (RD)-NPK, 100% RD of nitrogen (N) through PBSW with and without phosphorus (P) mineral fertilizer, 25 and 50% RD of N through PBSW + remaining N and P through mineral fertilizers. The application of 25% recommended dose of N through PBSW + remaining N and P through mineral fertilizers increased the total Fe, Zn, Mn and Cu uptake by soybean and wheat, soybean-grain equivalent yield of wheat and benefit: cost ratio compared to 100 and 50% RD-N through PBSW treatments and improved the status DTPA-Fe, Zn, Mn, Cu, Ni, Cd and Pb as compared to RD-NPK at all 3 soil depths. However, heavy metal status values were below the permissible limits. Fertigation of 25% N-PBSW along with mineral fertilizers not only help in improvement of the micronutrient status of soil but also prevent any adverse effect on soil health.

Key words *:* Heavy metal, Micronutrients, Soybean, Spentwash, Uptake, Wheat, Yield

Distilleries are one of the most important agro-based industries in India, producing alcohol from molasses, a by-product of sugar factories. Cane molasses, the third important by-product is an ideal medium, which is used in the distilleries for the production of alcohol. The molasses fermented with yeast and alcohol is distilled from fermented wash leaving behind waste water generally known as spentwash. The disposal of spentwash is of serious concern its large volume as well as due to its high biological oxygen demand and chemical oxygen demand. The direct discharge of this spentwash to aquatic bodies and land causes severe pollution. The spentwash doesn't contain any toxic metals, as it is mainly waste from plant material; rather contains very high concentrations of organic carbon, nitrogen, phosphorus and potassium. It also contains considerable amount of micronutrients and plant-growth hormones. The application of spentwash increased the uptake of zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn) in maize and wheat compared to control and the highest total uptake of these were found at lower dilution levels than at higher dilution levels (Zalawadia and Raman, 1994). Mineralization of organic material as well as nutrients present in the spentwash was responsible for increased availability of plant nutrients and increasing crop production by using it as a source of irrigation after proper dilution.

Soybean–wheat cropping system has emerged as an important cropping system only after 1980 with the introduction of soybean as a rainy season (*kharif*) crop in wheat–growing areas of the country particularly under irrigated condition. Nutrient transfer during sequenced cropping is important for the existing and subsequent crops. Soybean is susceptible to salts, however, wheat is salt tolerant (Torech and Thompson, 1993). Primary treated biomethanated spentwash (PBSW) contains more amounts of salts and its effect can be monitored on both crops, where one is susceptible and the other is tolerant to salts. In this context, the present investigation was undertaken using of PBSW as liquid manure particularly for

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soybean–wheat cropping sequence to study the effect of fertigation of PBSW on micronutrient, heavy metal status of soil and uptake of nutrient, economics and yield of soybean -wheat cropping sequence.

MATERIALS AND METHODS

The long-term field experiment was undertaken during the third (2009–10) and fourth years (2010–11), which was initiated during 2007–08 on fixed site at Post Graduate Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra (India). The experimental farm is situated in between 19^0 47' N and 19^0 57' N latitude and between 74°18' and 74°19' East longitude. Climatically the area belongs to semi-arid zone with an average rainfall of 519 mm. Mean maximum temperature was 31.3°C and 30.8°C during 2009–10 and 2010–11 respectively, while minimum temperature was 17.2°C and 18.1°C for 2009–10 and 2010–11 respectively. Average annual relative morning and evening humidity during the crop-growth period from soybean sowing to wheat harvest was 83.8 and 47.7% in both the years. Total rainfall during the crop-growth period of soybean was 441 (26 rainy days) and 798 (28 rainy days) and for wheat it was 148 (9 rainy days) and 103 (6 rainy days) mm during 2009–10 and 2010–11 respectively. The experimental soil was calcareous belonging to Sawargaon series of isohyperthermic family of Vertic haplustepts. The initial experimental soil (before start of experiment during 2007–08) was alkaline (pH 8.40), having electrical conductivity 0.40 dS/m and soil available N (alkaline $KMnO_4$), P (Olsen P) and K (NH_4OAc) contents were 190, 8.50 and 582 kg/ha respectively. DTPA-extractable micronutrients (mg/kg) Fe, Mn, Cu and Zn were 5.65, 11.86, 3.86 and 0.52 respectively. The experiment was laid out in randomized block design with 4 replications. Five treatments comprised recommended dose (RD)-NPK (T_1), 100% RD of N through primary treated biomethonated spentwash (PBSW) without P mineral fertilizer (T_2), 100% RD of N through PBSW + remaining P through mineral fertilizer (T_3), 50% RD of N through PBSW + remaining N and P through mineral fertilizers (T_4) and 25% RD of N through PBSW + remaining N and P through mineral fertilizers (T_5). The quantity of PBSW 35211 (1 : 0.022 water : spentwash), 35211 (1 : 0.022 water: spentwash), 17606 (1 : 0.011 water : spentwash) and 8803 (1 : 0.006 water : spentwash) litre/ha N content basis was mixed with irrigation water and applied to treatments T_2, T_3, T_4 and T_5 respectively, in 2 equal splits for soybean during the second and third irrigation during 2009–10 was done, while during 2010–11, due to continuous rains application of PBSW through irrigation was not possible. The quantity of PBSW 85714 (1 : 0.036 water : spentwash), 85714 (1 : 0.036 water : spentwash), 42857 (1 : 0.018 water: spentwash) and 21428 (1 : 0.009 water: spentwash) litre/ha on N content basis was mixed with irrigation water and applied to treatments T_2, T_3, T_4 and T_5 respectively in 3 equal splits for wheat at third, fourth and fifth irrigation during 2009–10 and 2010–11. The irrigation water used for irrigating soybean and wheat had low salinity and sodicity. The crop spacing was 30 cm × 10 cm (row × plant) for soybean and 22.5 cm (row) for wheat. Recommended dose fertilizer (RDF) was applied as basal for soybean (50:75 N:P/ha) as per the treatments. The RDF for wheat was 120:60:40 kg (N:P:K/ha), out of which half dose of N (60 kg/ha) and full dose of 60 kg P/ha and 40 kg K/ha in treatment T_1 was applied basal. In treatments T_2 and T_3 the 100% and in T_4 the 50% dose of N and in T_5, the 25 % N dose were applied through PBSW and 25% dose of N at sowing was supported through mineral fertilizer. The remaining half dose of N was applied 21 days after sowing in treatments T_1, T_4 and T_5. The sources of N, P and K were urea, single superphosphate and potassium chloride respectively. Standard agronomic packages of practices were adopted in both the crops. The PBSW was obtained from the distillery of Sugar Factory, Rahuri, Dist. Ahmednagar, Maharashtra. The PBSW had pH 7.48, EC 36.46 dS/m, BOD 5443 and COD 24874 mg/L, K^+ 0.99 %. Second initial soil samples were collected from 0–15, 15–30 and 30–60 cm depths from each plot at the time of harvesting of second year wheat, and further soil samplings were done at the time of harvesting third and fourth year soybean and wheat during 2009–10 and 2010–11. These samples were analysed for DTPA extractable micronutrients (Fe, Mn, Cu, Zn) and heavy metals (Ni, Cd, Pb) by Lindsay and Norvell (1978). The plant samples of soybean and wheat were collected at the time of harvesting; the grain and straw samples were collected separately from each plot. The samples were oven dried at 60°C. Dried samples were ground and digested with rapid nitric perchloric acid digestion method for micronutrients, viz. Fe, Mn, Cu, Zn (Zoroski and Bureau ,1977). The statistical analysis of the data was carried out by using standard statistical methods of analysis of variance (Panse and Sukhatme, 1985).

RESULTS AND DISCUSSION

Soil micronutrient availability and heavy metal status

DTPA-Fe, Zn, Mn and Cu in soil: The DTPA-Fe, Zn, Mn and Cu in soil was significantly influenced by different treatments at all 3 soil depths (Table 1). The highest pooled DTPA-Fe, Zn, Mn and Cu content in soil was observed in 100% N-PBSW and the lowest pooled in RD-NPK at all the soil depths. As the dose of PBSW was increased from 25 to 100% N, the pooled DTPA-Fe, Zn, Mn and Cu also increased proportionately in all the 3 depths.

The highest pooled DTPA-Fe, Zn, Mn and Cu content in soil observed in 25% recommended N through PBSW + remaining N and P through mineral fertilizers compared to RD-NPK at all the soil depths. The treatments RD-NPK, 25 and 50% N-PBSW + remaining N and P through mineral fertilizers showed lower pooled DTPA-Fe, Zn, Mn and Cu content in soil compared to 100 % N- PBSW + without and with P fertilizer. This might be due to the more uptake of Fe, Zn, Mn and Cu by soybean and wheat crop in both the years as well as less or no addition of PBSW as compared to 100% N-PBSW treatments. The 100% N-PBSW without P mineral fertilizer was statistically at par with 100% N-PBSW + P at all soil depths for DTPA Fe, Zn, Mn and Cu except at 0–15 cm soil depth for Fe. The increase in the fertigation quantity of PBSW increased the DTPA-Fe, Zn, Mn and Cu contents in soil. The DTPA-Fe, Zn, Mn and Cu contents in soil were above the critical level in all the treatments of fertigation. The higher and sufficient values of DTPA-Fe and Zn contents in soil were observed at higher levels of PBSW. The increase in availability of Fe, Zn, Mn and Cu might be due to direct contribution from the PBSW as well as solubilization and chelation effect of organic matter added through PBSW. Devarajan *et al.* (1996) also reported that the available Fe of the post-harvest soil increased from 2.3 to 3.2 ppm due to irrigation with 10 times diluted distillery effluent. Sukanya and Meli (2004) reported that N, P, K, Zn, Cu, Fe and Mn soil contents were higher in plots irrigated with effluent. The levels of organic carbon, macro and micronutrients were significantly increased due to effluent addition (Gopal *et al.,* 2001). The micronutrient content of the post-harvest soil has shown a steady increase over the years and the maximum increase was found in the treatments that received the highest dose of post-methanation effluent, viz. preplant @ 5 lakh L/ha and fertigation 1:10 times dilution treatments (Anandakrishanan *et al.,* 2009).

DTPA-Ni, Cd and Pb content in soil: The significantly lowest pooled DTPA Ni, Cd and Pb contents in soil were observed in treatment RD-NPK compared to PBSW treatments at all the 3 soil depths. The highest pooled DTPA-Ni, Cd and Pb contents in soil were observed in treatment 100% N-PBSW with and without P mineral fertilizer at all the soil depths over rest of the other treatments. The more prominent of DTPA-Pb was observed 100% N-PBSW with and without P mineral fertilizer compared to 25 and 50% N-PBSW + remaining N and P-mineral fertilizers, but these values were below permissible limit in pooled means (Table 2). The increase in dose of fertigation of PBSW increased the pooled DTPA-Ni, Cd and Pb con-

Table 1. Effect of fertigation of PBSW on DTPA-Fe, Zn, Mn and Cu at harvesting (pooled mean of 2 years)

Treatment	Soil depth (cm)	DTPA Fe (µg/g)		DTPA Zn (µg/g)		DTPA Mn (µg/g)		DTPA Cu (µg/g)	
		Initial#	Pooled mean	Initial#	Pooled mean	Initial#	Pooled mean	Initial#	Pooled mean
T_1, RD-NPK	0–15	5.70	5.72^{e}	0.60	0.47^{b}	12.2	11.73^{b}	4.10	3.88^{b}
	15–30	4.98	5.47^{c}	0.51	0.47^{c}	11.2	10.58^{c}	3.44	3.65^{c}
	30–60	4.70	5.37^{c}	0.40	0.43^{c}	9.3	9.17^{d}	3.10	3.42^{c}
T_2, 100% N-PBSW	0–15	7.64	7.40^{a}	0.82	0.81^{a}	20.7	14.52^{a}	4.24	5.66^{a}
	15–30	7.10	7.50^{a}	0.66	0.79^{a}	18.5	15.09^{a}	3.98	5.81^{a}
	30–60	6.90	7.51^{a}	0.62	0.71^{a}	11.3	12.27^{ab}	3.27	5.53^{a}
T_3, 100% N-	0–15	7.12	6.95^{b}	0.78	0.74^{a}	17.2	14.29^{a}	4.14	5.46^{a}
PBSW + P	15–30	6.50	7.38^{ab}	0.67	0.79^{a}	16.7	14.62^{a}	3.58	5.40^{ab}
	30–60	6.10	7.25^{a}	0.62	0.71^{a}	10.9	13.11^{a}	3.17	5.31^{a}
T_4, 50% N-PBSW +	0–15	6.88	6.58^{c}	0.70	0.66^{a}	16.5	12.60^{b}	3.92	5.07^{a}
remaining N and	15–30	6.10	6.84^{ab}	0.60	0.68^{b}	13.0	12.82^{b}	3.48	4.98^{ab}
P mineral fertilizer	30–60	5.70	6.64^{b}	0.48	0.66^{ab}	11.1	11.34^{bc}	3.10	4.64^{ab}
T_5, 25 % N- PBSW +	0–15	6.42	6.26^{d}	0.66	0.66^{a}	14.8	11.99^{b}	3.96	4.33^{b}
remaining N and	15–30	5.73	6.61^{b}	0.52	0.61^{b}	11.9	12.07^{b}	3.56	4.48^{b}
P – mineral fertilizer	30–60	5.30	6.52^{b}	0.42	0.61^{b}	10.50	10.69^{cd}	3.12	4.27^{bc}
SEm±	0–15	0.034	0.101	0.040	0.039	0.09	0.43	0.104	0.201
	15–30	0.047	0.262	0.092	0.033	0.12	0.49	0.125	0.316
	30–60	0.037	0.140	0.053	0.032	0.12	0.49	0.147	0.298
CD (P=0.05)	0–15	0.105	0.312	0.123	0.12	0.28	1.31	NS	0.62
	15–30	0.145	0.808	NS	0.10	0.36	1.51	NS	0.97
	30–60	0.115	0.433	0.164	0.10	0.38	1.52	NS	0.92

Means followed by the same letters (a,b,c,d) in a column are not different at 0.05 probability level.
Second initial soil samples were collected from each plot at the time of harvest of second year wheat.

Table 2. Effect of fertigation of PBSW on DTPA-Ni, Cd and Pb at harvesting (pooled mean of 2 years)

Treatment	Soil depth (cm)	DTPA-Ni (µg/g)		DTPA Cd (µg/g)		DTPA Pb (µg/g)	
		Initial#	Pooled mean	Initial#	Pooled mean	Initial#	Pooled mean
T_1, RD-NPK	0–15	0.043	0.051[d]	0.012	0.015[c]	0.038	0.043[e]
	15–30	0.043	0.050[e]	0.010	0.013[c]	0.036	0.040[d]
	30–60	0.042	0.045[c]	0.010	0.012[b]	0.038	0.042[d]
T_2, 100% N-PBSW	0–15	0.054	0.061[a]	0.018	0.021[a]	0.052	0.059[a]
	15–30	0.055	0.062[a]	0.016	0.019[b]	0.052	0.061[a]
	30–60	0.053	0.059[a]	0.017	0.019[a]	0.053	0.061[a]
T_3, 100% N-PBSW + P	0–15	0.055	0.061[a]	0.017	0.020[a]	0.049	0.056[b]
	15–30	0.054	0.060[b]	0.017	0.022[a]	0.049	0.055[b]
	30–60	0.051	0.060[a]	0.016	0.019[a]	0.049	0.056[b]
T_4, 50% N- PBSW + remaining N and P - mineral fertilizer	0–15	0.050	0.056[b]	0.015	0.018[b]	0.043	0.050[c]
	15–30	0.051	0.058[c]	0.011	0.015[c]	0.044	0.050[c]
	30–60	0.050	0.058[a]	0.013	0.014[b]	0.044	0.052[bc]
T_5, 25% N- PBSW + remaining N and P - mineral fertilizer	0–15	0.048	0.053[c]	0.014	0.016[c]	0.042	0.047[d]
	15–30	0.049	0.056[d]	0.010	0.013[c]	0.040	0.048[c]
	30–60	0.047	0.052[b]	0.010	0.012[b]	0.042	0.048[c]
SEm±	0–15	0.0023	0.0003	0.002	0.0003	0.002	0.0004
	15–30	0.0017	0.0002	0.001	0.0004	0.003	0.0006
	30–60	0.0025	0.0010	0.001	0.0004	0.003	0.0011
CD (P=0.05)	0–15	0.0071	0.0009	NS	0.0009	0.005	0.0012
	15–30	0.0053	0.0008	0.004	0.0013	0.010	0.0018
	30–60	NS	0.0030	0.003	0.0014	0.008	0.0033

Means followed by the same letters (a,b,c,d) in a column are not different at 0.05 probability level
Second initial soil samples were collected from each plot at the time of harvest of second year wheat.

tents in soil. The DTPA-Ni, Cd and Pb contents in soil increased gradually compared to initial values in all the treatments at all the soil depths. The 100% RD N- PBSW treatments showed the highest Ni, Cd and Pb contents in soil due to fertigation of PBSW (Table 2). This was explained by Li and Shuman (1997) as the application of vinasse may increases some metal's mobility, because soluble organic chelates can form water-soluble complexes with metals. Ramalho *et al.* (2001) stated that the use of vinasse for more than 15 years in volumes of 300 m^3/ha/year did not increase the concentrations of the heavy metals above toxicity level. The metallic cations (Fe, Mn, Zn, Cu, Ni, Cd and Pb) status increased as a consequence of incorporation of either pressmud or spentwash in integration with phosphogypsum (Pagaria and Totawat, 2007). The concentration of heavy metals were found higher in the soil irrigated with effluent (Ale *et al.*, 2008). The lowest amount of pooled DTPA-Ni, Cd and Pb contents in soil were observed at 30–60 cm soil depth compared to the other soil depths. Since metals are immobile in soil, these accumulate mainly in surface soils which is the zone of prime root activity in crop (Jayabaskaran and Sriramulu, 1996). Fertigation of distillery effluents concentrations such as 5%, 10%, 25%, 50%, 75% and 100% increased the Cd and Pb in soil (Kumar and Chopra, 2011).

Pooled total uptake of micronutrients

Total uptake of Fe, Zn, Mn and Cu by soybean and wheat: The significantly highest pooled total iron, zinc, manganese and copper uptake by soybean and wheat was recorded in treatment 25% N-PBSW + remaining N and P - mineral fertilizers than remaining the treatments (Table 3). The sequence of total iron, zinc, manganese and copper uptake by soybean and wheat was $T_5 > T_1 > T_4 > T_3 > T_2$. The 25% N-PBSW + remaining N and P - mineral fertilizers was at par with RD-NPK for total iron, zinc, manganese and copper uptake by soybean and wheat except zinc and copper uptake by wheat. The highest total uptake of total iron, zinc, manganese and copper uptake by soybean and wheat was observed 25% N-PBSW + remaining N and P mineral fertilizers due to application of low dose of PBSW along with mineral fertilizers that increased the availability of nutrients by increasing rate of mineralization, thereby increased in the yield and ultimately increased total total iron, zinc, manganese and copper uptake by soybean and wheat. The application of diluted spentwash increased the uptake of iron, zinc, manganese and copper in maize and wheat compared to the control and the highest total uptake of these were found at lower dilution levels than at higher dilution levels (Pujar, 1995; Zalawadia *et al.*, 1997; Sukanya *et al.*, 2002). The lowest total uptake of Fe, Mn, Zn and Cu by soybean and wheat was observed in 100% N-PBSW without P mineral fertilizer. This might be due to the fact that PBSW had high amount of soluble salts which can reduce plant growth or damage the plants due to osmotic effect (causing water deficit), toxic effects of ions Na^+ and Cl^- and imbalance of the uptake of essential nutrients, which decreased the yield of soybean and wheat crop, ultimately decreased the micronutrient uptake. The uptake of DTPA-micronutrients by maize crop increased up to 60 m^3/ha level and above this level the decrease in uptake showed in detrimental effect of high levels of PBSW (Khatal *et al*., 2009).

Yield of soybean and wheat

Grain and straw yield of soybean: The highest grain and straw yields of soybean in pooled means were recorded in 25% recommended N through PBSW + remaining N and P through mineral fertilizers and it was followed by RD-NPK (Table 4), might be owing to mineralization of organic matter of PBSW and more availability of nutrients including micronutrients to soybean during the mineralization process. Bhosale *et al*. (2009) reported that the grain and straw yields of soybean were significantly increased over the control with the application of various levels of PBSW along with mineral fertilizers. Rath *et al.* (2011) stated that the growth parameters (growth and chlorophyll content) of sugarcane plant showed an increasing trend from the control, 50% distillery spentwash except 100% distillery spentwash. The lowest pooled means of grain and straw yield of soybean were noticed in 100% recommended N through PBSW with and without mineral P fertilizer. This might be due to adverse effects of PBSW on the rhizosphere environment because of its high BOD and COD and consequent ill-effects on the growth of root and shoots of the plant. The high biological oxygen demand was obviously due to increase in CO_2, increase in temperature and formation of organic acids during decomposition of organic matter and thus net immobilization of nutrients. Pujar (1995) studied the distillery effluent as a source of irrigation at higher dilutions and reported that 50 times dilution proved better in wheat but a lower dilution (10 times) proved superior in maize and sugarcane. Bhat *et al*. (2011) reported that there was decrease in cane yield at higher dilutions.

Grain and straw yield of wheat: The highest pooled grain and straw yields of wheat were recorded in treatment RD-NPK followed by 25% recommended N through PBSW + remaining N and P through mineral fertilizers (Table 4). The treatment RD-NPK was at par with 25% recommended N through PBSW + remaining N and P through mineral fertilizers for straw yield of wheat. Among the PBSW treatments, the highest pooled grain yield of wheat was recorded in 25% recommended N through PBSW + remaining N and P through mineral fertilizers. The comparatively small amount of PBSW in 25 and 50% N-PBSW compared to 100% N-PBSW treatments was undergone speedy decomposition due to high amount of mineral fertilizers, which was helpful for increasing soil available nutrients rather than immobilization as seen in 100% N-PBSW treatments. The reduction in grain and straw yield of wheat was observed in 100% recommended N through PBSW + with and without P mineral fertilizer. This might be due to increasing quantity of PBSW application which contains high amount of organic matter, i.e. material with high BOD and COD, it contains excess amount of various cations and anions may have an adverse effect on crop growth by water and other metabolic process of plant (Singh and Bahadur, 1998; Sukanya *et al*., 2002; Bhat *et al*., 2011).

Grain equivalent yield: The highest pooled soybean grain equivalent yield of wheat was noticed in RD-NPK and it was similar with 25 % N-PBSW + remaining N and P - mineral fertilizers (Table 4). It clearly indicated that 25% N fertilizer could be saved through fertigation of PBSW. The lowest pooled soybean grain equivalent yield of wheat was noticed in 100% N- PBSW+ with and with-

Table 3. Effect of fertigation of PBSW on pooled total iron, zinc, manganese and copper uptake by soybean and wheat (pooled mean of 2 years)

Treatment	Fe uptake(g/ha)		Zn uptake (g/ha)		Mn uptake (g/ha)		Cu uptake (g/ha)	
	Soybean	Wheat	Soybean	Wheat	Soybean	Wheat	Soybean	Wheat
T_1, RD-NPK	640^{ab}	2177^{a}	111^{ab}	325^{b}	184^{ab}	631^{ab}	34^{ab}	163^{b}
T_2, 100% N-PBSW	274^{d}	1327^{b}	54^{d}	146^{d}	81^{d}	342^{c}	15^{d}	100^{d}
T_3, 100% N-PBSW + P	439^{c}	1575^{b}	79^{c}	171^{c}	129^{c}	380^{c}	23^{c}	106^{d}
T_4, 50% N- PBSW + remaining N and P - mineral fertilizer	567^{b}	2263^{a}	101^{b}	320^{b}	177^{b}	597^{b}	32^{b}	152^{c}
T_5, 25 % N-PBSW + remaining N and P - mineral fertilizer	716^{a}	2300^{a}	119^{a}	380^{a}	212^{a}	655^{a}	37^{a}	174^{a}
SEm ±	39	146	5	8	11	21	1	2
CD (P=0.05)	119	450	16	23	34	64	3	6

Means followed by the same letters (a,b,c,d) in a column are not different at 0.05 probability level

Table 4. Effect of fertigation of PBSW on pooled yield and economics by soybean and wheat (pooled mean of 2 years)

Treatment	Soybean yield (t/ha)		Wheat yield (t/ha)		Soybean grain equivalent yield of wheat (t/ha)	Cost of cultivation (× 10^3 ₹/ha)	Net returns (×10^3 ₹/ha)	Benefit: cost ratio
	Grain	Straw	Grain	Straw				
T_1, RD-NPK	0.593	1.748	3.692[a]	5.022[a]	2.497[a]	41.0	27.1	1.63
T_2, 100% N-PBSW	0.319	0.872	1.728[d]	2.880[b]	1.172[c]	31.2	0.63	1.03
T_3, 100% N-PBSW + P	0.404	1.297	2.077[c]	3.001[b]	1.414[c]	34.9	4.9	1.17
T_4, 50% N- PBSW + remain. N and P-mineral fertilizer	0.551	1.550	3.114[b]	4.435[a]	2.106[b]	37.5	20.6	1.59
T_5, 25% N-PBSW + remaining N and P - mineral fertilizer	0.645	1.792	3.358[b]	4.916[a]	2.273[a]	38.8	26.0	1.65
SEm±	0.040	0.113	0.101	0.223	0.081			
CD (P=0.05)	NS	NS	0.312	0.671	0.246			

Means followed by the same letters (a,b,c,d) in a column are not different at 0.05 probability level

out P mineral fertilizer.

Economics of cropping sequence

The benefit: cost ratio of cropping sequence was highest in treatment 25 % recommended N through PBSW + remaining N and P through mineral fertilizers. The lowest net returns and benefit: cost ratio of soybean and wheat was recorded in treatment 100% N-PBSW without P-mineral fertilizer. The highest mean of benefit: cost ratio of cropping sequence was observed in treatment 25% N-PBSW + remaining N and P - mineral fertilizers and followed by RD-NPK (Table 4). This might be owing to higher grain yield of soybean and wheat crop obtained in these treatments compared to other treatments. Our results confirm the fundings of Balasubramaniam (2013).

Thus application of 25% RD of N through fertigation of PBSW for soybean in 2 equal splits and for wheat 3 equal splits + remaining N and P through mineral fertilizers increased the grain and straw yields of soybean and wheat over the rest of other PBSW treatments and increased availability and uptake of micronutrients (Fe, Zn, Mn and Cu). However, DTPA-heavy metal (Ni, Cd and Pb) status increased in all PBSW treatments and these values were below the critical /permissible limit in soil.

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