



Impact of post biomethanated spentwash on soil properties, nutrient uptake and yield of soybean – wheat cropping sequence

B. M. Kamble^{1*} and A. N. Deshpande

Agricultural Research Station, Kasabe Digraj, Sangli- 416 305 (Maharashtra), INDIA

¹Department of Soil Science and Agricultural Chemistry, Mahatma Phule Agricultural University, Rahuri, Ahamadnagar (Maharashtra), INDIA

*Corresponding author: E-mail: bmkamble2007@rediffmail.com

Received: July 21, 2014; Revised received: September 04, 2014; Accepted: October 27, 2014

Abstract: A field experiment was conducted on Sawargaon series of isohyperthermic family of *Vertic haplustepts* to study the effect of application of primary treated biomethanated spentwash (PBSW) through irrigation on soil properties, nutrient uptake and yield of soybean – wheat cropping sequence. The bulk density and hydraulic conductivity of soil were improved in 100% recommended dose (RD) of N through PBSW with and without P chemical fertilizer at soil depths of 0-15 and 15-30 cm. The lowest soil pH, calcium carbonate and highest electrical conductivity, organic carbon, available K, exchangeable sodium (Na), exchangeable sodium percentage (ESP), cation exchange capacity (CEC), sodium adsorption ratio (SAR) and pooled bacterial, fungal and actinomycetes populations in surface (0-15 cm) soil depth were observed in 100% RD of N through PBSW + with and without P chemical fertilizer at all three soil depths (0-15, 15-30 and 30-60 cm) over the other treatments. The highest pooled available soil P was recorded in 50% RD of N through PBSW application through irrigation and remaining N and P through chemical fertilizers in all three soil depths. The significantly highest total NPK uptake by cropping sequence and highest mean Benefit : Cost (B:C) ratio of soybean and wheat was recorded in 25 % RD of N through PBSW + remaining N and P through chemical fertilizers over the rest of the treatments. The 25 % N-recommended dose of soybean and wheat crop can be replaced by application of PBSW through irrigation in sequence without disturbing soils by salt load.

Keywords: Economics, Effluent, Soybean-wheat sequence, Soil properties

INTRODUCTION

Fertilizers play an important role in increasing productivity and production. An estimated contribution of fertilizers as an input is 50 - 60 %. However, the cost of fertilizers is increasing day by day, so that there is urgent need for utilization of available alternative resources, viz., farm yard manure (FYM), compost, green manure, recycled crop residues and agricultural industrial wastes, e.g., spentwash, which is the cheapest source of nutrients for plant through the application in appropriate quantity without affecting soil health (Joshi *et al.*, 1994).

India is the largest sugarcane producer in the world and a large number of sugar factories produce substantial amounts of molasses. Molasses serves as raw material for production of alcohol. The liquid left after distillation, known as spentwash, vinasse, etc., can be utilized in agriculture as liquid manure. The quantity of spentwash produced in distillery is about 12 to 15 times more than that of alcohol produced (Manohar Rao, 1983). The spentwash produced in this process is called raw spentwash and when it is treated with bacteria for methanation the remaining liquid is called primary biomethanated spentwash (PBSW). If

the distillery effluent is used after proper dilution, crops show good response to distillery effluent application (Joshi *et al.*, 1994; Zalawadia and Raman 1994). Soybean-wheat cropping system has emerged as an important cropping system only after 1980 with the introduction of soybean as a *kharif* crop in wheat -growing areas of the country particularly under irrigated system. Different doses of raw spentwash have been tried in combination with different types of fertilizers in agricultural fields and there are reports of both positive and negative impacts. In this context, the present investigation was undertaken for the use of PBSW as liquid manure particularly for soybean- wheat cropping sequence in command area. Because of high biological oxygen demand (BOD), chemical oxygen demand (COD), high salt content, acidic pH of raw spentwash can affect the plant growth, but PBSW having low BOD, COD and comparatively low salt content and neutral pH can be tolerated by plant and judicious use can provide a cheapest nutrient source to the plants. However, continuous long term uses of PBSW can also deteriorate the soil health. It should be monitored by taking research trials with the following objectives: i) to study the effect of PBSW application through irrigation on physical, chemical and biological proper-

ties of soil and ii) to study the effect of PBSW application through irrigation on nutrient uptake and yield of soybean and wheat cropping sequence.

MATERIALS AND METHODS

The field experiment was conducted during 2009-10 and 2010-11 for research study on fixed site of Sawargaon series of isohyperthermic family of *Vertic haplustepts*; however, the field experiment was initiated during 2007-08 at Post Graduate Research Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India. The initial experimental soil belonging to was alkaline (pH 8.40), having EC 0.40 dS m⁻¹, calcareous (CaCO₃ 15.80 %), clayey in texture with bulk density of 1.42 Mg m⁻³, hydraulic conductivity 0.37 cm hr⁻¹, mean weight diameter 0.14 mm, exchangeable Na⁺ (0.71 cmol (p⁺) kg⁻¹) and exchangeable sodium percentage (1.44). The soil had available N (alkaline KMnO₄) 190 kg ha⁻¹, P (Olsen P) 8.50 kg ha⁻¹ and K (NH₄OAc) 582 kg ha⁻¹ and saturation paste extract of soil having pHs-8.12 ECe-0.88 dS m⁻¹, Na⁺ was 9.5 meq L⁻¹. The experiment was laid out in randomized complete blocks design with five treatments, viz., recommended dose (RD)-NPK (T₁), 100% RD of N through PBSW without P chemical fertilizer (T₂), 100% RD of N through PBSW + remaining P through chemical fertilizer (T₃), 50 % RD of N through PBSW + remaining N and P through chemical fertilizers (T₄) and 25 % RD of N through PBSW + remaining N and P through chemical fertilizers (T₅) and replicated in four times. The crop spacing was 30 cm X 10 cm (row X plant) for soybean and 22.5 cm (row) for wheat. The basal recommended dose of fertilizer (RDF) was applied for soybean (50:75 N:P₂O₅ kg ha⁻¹) as per the treatments. The RDF for wheat was 120:60:40 (N:P₂O₅:K₂O kg ha⁻¹), out of which half dose of N (60 kg ha⁻¹) and full dose of 60 kg P₂O₅ ha⁻¹ and 40 kg K₂O ha⁻¹ in treatment T₁ as basal dose and remaining ½ dose of N was applied after 21 days of sowing. In treatment T₂, T₃ -100 %, T₄ -50 % and in T₅ 25 % N dose was applied through PBSW. In T₅ 25 % dose of N at sowing was supported through chemical fertilizer. The PBSW was applied at 2nd and 3rd irrigation in two equal splits for soybean during 2009-10. The application of PBSW through irrigation was not possible due to continuous rains in the year 2010-11. The application of PBSW in three equal splits for wheat at 3rd, 4th and 5th irrigation during the year 2009-10 and 2010-11 was done as per treatments (Tables 1 and 2). All cultural practices including gap filling, thinning, weeding, plant protection measures and other cultural practices were done in both the crops as per the recommendations of Mahatma Phule Agricultural University. The total rainfall during the crop growth period of soybean was 441mm (26 rainy days) and 798mm (28 rainy days) and for wheat it was 148mm (9 rainy days) and 103 mm (6 rainy days) during the year 2009-10 and 2010-

11, respectively. The irrigation water used for irrigating soybean and wheat had low salinity and sodicity. The PBSW was obtained from the distillery of Shri. Baburaoji Tanpure co-operative sugar factory, Rahuri, district Ahmednagar of Maharashtra State which had mean characters viz., pH 7.48, EC 36.48 dS m⁻¹, BOD 5443 and COD 24874 mg L⁻¹, K⁺ 0.98 %, Ca²⁺, Mg²⁺, Na⁺, SO₄²⁻ and Cl⁻ were 3422, 2923, 2391, 2643 and 2215 mg L⁻¹, respectively.

Soil, plant sampling and analysis: The initial soil samples were collected at 0-15, 15-30 and 30-60 cm depths from each plot at the time of wheat harvest of 2nd year and further soil samples were done at the time of soybean and wheat harvest in the 3rd and 4th year (2009-10 and 2010-11). These samples were analyzed for physical (two depths:0-15 and 15-30 cm), chemical parameters (three depths:0-15, 15-30 and 30-60 cm) and microbial count (one depth:0-15 cm). The soil samples were dried in shade ground and sieved through 0.5 mm sieve for organic carbon and 2 mm sieve for general analysis. Soil samples were analysed for bulk density by core sampler method (Blake and Hartage,1986), hydraulic conductivity by constant head method (Klute and Dirksen, 1986). The soil pH and electrical conductivity were measured 1:2.5 soil suspension (Jackson, 1973). The organic carbon content of soil was determined by Walkley and Black method (Nelson and Sommers, 1982). The calcium carbonate (CaCO₃) content of soil was determined by rapid titration method (Allison and Moodier,1965). The exchangeable Na⁺ was estimated by flame photometer (Richard 1954). The cation exchange capacity (CEC) of soil was estimated by saturating solution of ammonium acetate + ammonium chloride and extracting solution of magnesium nitrate (Palemio and Rhoades, 1977). The exchangeable sodium percentage (ESP) was calculated as exchangeable Na⁺ divided by CEC multiplied by 100 (Richards 1954). The soil samples were analysed for available N by alkaline permanganate method (Subbiah and Asija, 1956), available P (Olsen- P) by 0.5 M NaHCO₃ extraction (Olsen *et al.*,1954), available K (NH₄OAc) by IN neutral NH₄OAc extraction on flame photometer (Knudsen *et al.*,1982). The microbial populations were estimated by serial dilution plate technique (Halvorson and Ziegler,1993). The saturated paste extracts of soil were prepared and analyzed for pH, EC, major cations viz., Na⁺, K⁺, Mg²⁺, Ca²⁺ and major anions viz.;HCO₃²⁻, Cl⁻ and SO₄²⁻ (Richards, 1954).

The plant and grain samples were collected at the time of harvest and analyzed for total N by micro-Kjeldahl method in H₂SO₄: H₂O₂ (1:1) digestion (Parkinson and Allen, 1975), total P by vanadomolybdate yellow colour method in nitric acid H₂SO₄:HClO₄:HNO₃ (1:4:10) digestion (Jackson, 1973) and total K on flame photometer in H₂SO₄:HClO₄:HNO₃ (1:4:10) (Chapman and Pratt, 1961). The statistical analysis was carried out by procedure suggested by Panse and

Sukhatme (1985).

RESULTS AND DISCUSSION

Effect of PBSW irrigation on physical properties

Bulk density: The highest pooled bulk density of soil was recorded in RD-NPK (T_1) in surface depth and subsurface soil depths. The lowest pooled mean bulk density of soil was noticed in T_2 and T_3 treatments as compare to RD-NPK as well as in both the years and both the soil depths (Table 3). The bulk density of soil was slightly reduced at wheat harvest 2010-11 as compare to initial values. The addition of colloidal organic matter through PBSW which is also readily oxidizable increased the pore space in soil and improved the physical properties. Hati *et al.* (2004) reported that the application of post-methanation effluent (PME) showed a significant improvement in the physical properties of soil. The mean weight diameter, per cent water-stable aggregation, saturated hydraulic conductivity and water retention at 0.033 MPa suction were significantly ($P < 0.05$) more while bulk density and penetration resistance was significantly less in PME-treated plots than that of control. Deshpande *et al.* (2012) reported that the physical properties [bulk density, mean weight diameter (MWD) of water-stable aggregates and hydraulic conductivity] of soil were improved in both layers of sodic soil (0–30 and 30–60 cm) as a result of the addition of increased doses of PBSW.

Hydraulic conductivity: The highest pooled hydraulic conductivity of soil was observed in treatment T_3 in surface depth (0.455 cm hr^{-1}) and T_2 in sub-surface depth (0.419 cm hr^{-1}) as compared to rest of other treatments. The significantly lowest hydraulic conductivity of soil (0.383 and 0.362 cm hr^{-1}) was found in RD-NPK over the rest of other treatments in 0–15 and 15–30 cm soil depths. The highest pooled hydraulic conductivity of soil was observed in surface depth as compared to subsurface depth. The highest hydraulic conductivity of soil was gradually increased at the end of experiment as compared to initial values (Table 3). The hydraulic conductivity of soil was increased due to the higher amount of colloidal organic matter present in the PBSW which resulted in aggregation of soil particles and thereby decrease in bulk density and increase in the pore space, aeration which improves the structure of soil (Hati *et al.*, 2004 and Deshpande *et al.*, 2012).

Effect of PBSW irrigation on chemical properties

Soil pH (1:2.5): The highest pooled soil pH (8.18, 8.14 and 8.12) was observed in treatment T_1 at all the soil depths. The highest decrease in soil pH was found in surface depth 0–15 cm as compare to below both the depths (15–30 and 30–60 cm). Among the PBSW application through irrigation treatments, the lowest pH (7.81, 7.84 and 7.91) was observed in treatment T_2 and highest was noticed in T_5 (8.01, 7.98 and 8.03) at all the soil depths (Table 4). As the dose of PBSW

increased there was decrease in pH in all three soil depths in both the years of experimentation and pooled mean. This might be due to high amount of application of PBSW, which contains high colloidal organic matter which releases organic acids (R-COOH) after decomposition that can reduce soil pH due to H^+ dissociation from carboxyl groups. The increase in spentwash application resulted in a notable decrease in the pH of soils (Saliha, 2003).

Electrical conductivity: The EC of all three soil depths was increased in all PBSW treatments as compared to without application of PBSW (RD-NPK) in both the years of study and in pooled mean. The highest pooled EC of soil (1.34, 1.51 and 1.65 dS m^{-1}) was recorded in treatment T_2 (100 % N - PBSW + without P chemical fertilizer) and it was at par with T_3 (1.18, 1.31 and 1.54 dS m^{-1}) in all the three soil depths. The lowest pooled EC of soil (0.57, 0.53 and 0.62 dS m^{-1}) was noticed in treatment T_1 (RD-NPK) and it was at par with treatment T_5 (25% N - PBSW + remaining N and P-chemical fertilizers) at 0–15 (0.75 dS m^{-1}) and 15–30 cm (0.88 dS m^{-1}) soil depths. The PBSW application through irrigation was increased EC of soil in all the treatments at the end of experiment as compare to initial values (Table 4). As there was increased PBSW increased soluble salt concentrations in soil. The increase in EC of soil due to increase in PBSW doses might be due to the fact that PBSW contains higher amounts of soluble salts (34.90–38.06 dS m^{-1}). Saliha (2003) reported that the EC of soil increased markedly due to accumulation of salts from spentwash.

Organic carbon: The highest pooled organic carbon content in soil (0.62 and 0.52 %) was recorded in (T_2) 100% N -PBSW + without P chemical fertilizer at 0–15 and 15–30 cm soil depths and it was at par with treatments T_1 (0.60 and 0.54 %) and T_3 (0.57 and 0.51 %) at 0–15 and 15–30 cm soil depths (Table 5). The lowest pooled organic carbon content in the soil (0.51 and 0.42 %) was noticed in treatment T_5 . The increase in soil organic carbon with increased levels of PBSW application might be cause of large quantities of colloidal organic matter added through PBSW. The order of organic carbon in different soil depths was 0–15 > 15–30 > 30–60 cm soil depth. This might be due to surface application of PBSW which enriches the surface soil layer with organic carbon and then this process was further extended to lower depths. In the treatments of 100 % N-PBSW + with and without P chemical fertilizer there was build up of organic carbon throughout the soil profile as compare to other treatments tested (Table 5). This was happen because the distillery effluent had a high concentration of colloidal forms of organic matter and its application led to increased organic carbon in post harvest soil. Deshpande *et al.*, (2012) stated that the significant increase in organic carbon was observed in both soil layers as a result of the addition of PBSW at 180 $\text{m}^3 \text{ha}^{-1}$.

Table 1. Nutrients applied through PBSW and chemical fertilizers to soybean.

Year 2009-10								
Treatment	PBSW (L ha ⁻¹)	Nutrients applied through PBSW (kg ha ⁻¹)			Nutrients applied through chemical fertilizers (kg ha ⁻¹)			
		N	P ₂ O ₅	K ₂ O	N	Urea	P ₂ O ₅	Single super phosphate
T ₁	-	-	-	-	50	108.7	75	468.75
T ₂	35211	50	16.6	345	-	-	-	-
T ₃	35211	50	16.6	345	-	-	58.4	365
T ₄	17606	25	8.3	172	25	54.4	66.7	417
T ₅	8803	12.5	4.15	86	37.5	81.5	70.8	442.8
Year 2010-11								
T ₁	-	-	-	-	50	108.7	75	468.75
T ₂	The application of PBSW through irrigation was not possible due to continuous rains in the year 2010-11.				-	-	-	-
T ₃					-	-	58.2	364
T ₄					25	54.4	66.6	416
T ₅					37.5	81.5	70.8	442.5

Table 2 . Nutrients applied through PBSW and chemical fertilizers to wheat.

Year 2009-10										
Treatment	PBSW (L ha ⁻¹)	Nutrients applied through PBSW (kg ha ⁻¹)			Nutrients applied through chemical fertilizers (kg ha ⁻¹)					
		N	P ₂ O ₅	K ₂ O	N	Urea	P ₂ O ₅	Single super phosphate	K ₂ O	Potassium chloride
T ₁	-	-	-	-	120	260	60	375	40	67
T ₂	85714	120	45	849	-	-	-	-	-	-
T ₃	85714	120	45	849	-	-	15	93	-	-
T ₄	42857	60	22.5	424	60	130	37.5	234	-	-
T ₅	21428.5	30	11.3	212	90	195.6	48.7	304.5	-	-
Year 2010-11										
T ₁	-	-	-	-	120	260	60	375	40	67
T ₂	86331	120	52	854	-	-	-	-	-	-
T ₃	86331	120	52	854	-	-	8	50	-	-
T ₄	43165	60	26	427	60	130	34	212	-	-
T ₅	21583	30	13	213	90	195.6	47	294	-	-

Calcium carbonate: The lowest pooled CaCO₃ content in soil (15.46, 15.68 and 15.79 %) was recorded in treatment T₂ at all the soil depths. The treatments T₂ (15.46 %) and T₃ (15.56 %) were at par with each other for pooled CaCO₃ content at 0-15 cm soil depth. The more amount of pooled CaCO₃ content in soil was present in 15-30 cm subsurface soil depth as compare to 0-15 and 30-60 cm soil depths. The highest pooled CaCO₃ content in soil was noticed in RD-NPK (16.70 and 17.09 %) at 0-15 and 15-30 cm soil depths as compare to rest of the treatments (Table 5). It clearly indicated that as the quantity of PBSW

applied through irrigation was increased it helped to decrease the CaCO₃ content of 0-15 and 15-30 cm soil depths. The continuous PBSW application through irrigation decreased the CaCO₃ content of all the three soil depths studied at the end of the experiment (wheat harvest 2010-11) over the initial soil values due to PBSW application through irrigation may be the result of decrease in soil pH and production of organic acids as a result of decomposition of organic matter, which had lead to the solubilization of CaCO₃ and thereafter it's leaching below the root zone. This might be due to more leaching of CaCO₃ due to heavy rainfall,

Table 3. Effect of PBSW application through irrigation on bulk density and hydraulic conductivity of soil at harvest of soybean and wheat.

Treatment	Soil depth (cm)	Bulk density (Mg m^{-3})			Pooled mean	Hydraulic conductivity (cm hr^{-1})			Pooled mean
		Initial	Soybean 2009-10	Wheat 2010-11		Initial	Soybean 2009-10	Wheat 2010-11	
T ₁	0-15	1.40	1.41 ^a	1.43 ^a	1.42 ^a	0.378	0.381 ^b	0.386 ^b	0.383 ^d
	15-30	1.45	1.46 ^a	1.47 ^a	1.46 ^a	0.354	0.359 ^b	0.365 ^b	0.362 ^d
T ₂	0-15	1.38	1.37 ^c	1.35 ^b	1.36 ^c	0.445	0.450 ^a	0.458 ^a	0.454 ^a
	15-30	1.42	1.42 ^b	1.40 ^c	1.41 ^c	0.412	0.417 ^a	0.421 ^a	0.419 ^a
T ₃	0-15	1.37	1.37 ^c	1.35 ^b	1.36 ^c	0.444	0.452 ^a	0.458 ^a	0.455 ^a
	15-30	1.42	1.42 ^b	1.40 ^c	1.41 ^c	0.409	0.414 ^a	0.419 ^a	0.417 ^b
T ₄	0-15	1.39	1.39 ^b	1.36 ^b	1.38 ^b	0.440	0.443 ^a	0.445 ^a	0.444 ^b
	15-30	1.44	1.43 ^b	1.42 ^b	1.43 ^b	0.385	0.388 ^a	0.390 ^{ab}	0.389 ^c
T ₅	0-15	1.40	1.40 ^{ab}	1.38 ^b	1.39 ^b	0.426	0.433 ^a	0.438 ^a	0.436 ^c
	15-30	1.45	1.45 ^a	1.44 ^b	1.44 ^b	0.384	0.386 ^a	0.389 ^{ab}	0.388 ^c
S.E.±	0-15	0.005	0.005	0.010	0.006	0.008	0.009	0.008	0.0006
	15-30	0.004	0.005	0.009	0.003	0.009	0.011	0.011	0.0005
CD (0.05)	0-15	0.015	0.016	0.032	0.019	0.026	0.027	0.026	0.0019
	15-30	0.013	0.015	0.026	0.010	0.027	0.035	0.035	0.0015

irrigation and high quantity of PBSW application. The significant reduction in calcium carbonate was observed in 0-30 and 30-60 cm soil layers as a result of the addition of PBSW at $180 \text{ m}^3 \text{ ha}^{-1}$ (Deshpande *et al.*, 2012).

Cation exchange capacity: The highest pooled CEC of soil $\{(53.83, 48.55 \text{ and } 47.60 \text{ cmol (p}^+) \text{ kg}^{-1})\}$ was observed in treatment T₃ at all the soil depths. The treatment T₃ was at par with treatments T₂ $\{(53.40, 48.16 \text{ and } 47.21 \text{ cmol (p}^+) \text{ kg}^{-1})\}$ and T₄ $\{(52.87, 47.69 \text{ and } 46.75 \text{ cmol (p}^+) \text{ kg}^{-1})\}$ at all three soil depths. Significantly lowest pooled CEC was noticed in all three soil depths studied in T₁ (RD-NPK). Similar trend of CEC at all the three soil depths was noticed at soybean and wheat harvest 2010-11. The CEC of soil was increased at the end of experiment (wheat harvest 2010-11) as compare to initial values at all the soil depths (Table 6). The highest CEC of soil was noticed in surface depth (0-15 cm) and decreased with increasing depth of soil in pooled means as well as in all the four seasons. As the PBSW application through irrigation quantity was increased the CEC of soil was also increased. This might be due to high amount of cations as well as organic matter in PBSW (Deshpande *et al.*, 2012).

Exchangeable Na⁺: The highest pooled exchangeable Na⁺ was observed in treatment T₂ $\{(2.36 \text{ cmol(p}^+) \text{ kg}^{-1})\}$ at 0-15 cm soil depth and treatment T₃ $\{(2.75 \text{ and } 2.72 \text{ cmol(p}^+) \text{ kg}^{-1})\}$ at 15-30 and 30-60 cm soil depths over the rest of other treatments. Among the PBSW treatments, the lowest pooled exchangeable Na⁺ was found in treatment T₅ $\{(1.86, 1.79 \text{ and } 1.64 \text{ cmol (p}^+) \text{ kg}^{-1})\}$ followed by treatment T₄ $\{(2.07, 2.17 \text{ and } 2.05 \text{ cmol (p}^+) \text{ kg}^{-1})\}$. The exchangeable Na⁺ was gradually increased in all the soil depths in PBSW treatments at

the end of experiment (wheat harvest 2010-11) as compare to initial soil values and this increase was more substantial in treatments T₂ and T₃. The exchangeable Na⁺ was gradually increased due to continuous application of PBSW with high salt load, which increased salt concentration in clayey soils, increased conductivity and there by saturation of salts in lower soil depths (Table 6). In due course of time this saturated soil depths with salts particularly with Na⁺ were responsible for increasing exchangeable Na⁺. The presown application of PBSW @ $50,000 \text{ L ha}^{-1}$ increased exchangeable Na⁺ of soil was $0.11 \text{ cmol (p}^+) \text{ kg}^{-1}$ (5.47 to $5.58 \text{ cmol (p}^+) \text{ kg}^{-1}$) at harvest of pearl millet (Deshpande *et al.*, 2009).

Exchangeable sodium percentage: The higher pooled ESP of soil was recorded in 100 % N-PBSW + without P chemical fertilizer at all the soil depths. The increased ESP of soil due to the increasing levels of PBSW, which contain high amount of salt load particularly sodium was responsible for increased exchangeable sodium as well as ESP (Table 7). Among the PBSW treatments, the lowest ESP of soil was noticed in 25% N-PBSW + remaining N and P-chemical fertilizers as compare to T₃ and T₂ in all the seasons of experiment and pooled means. Increased levels of PBSW application fertigation increased ESP of soil. Kayalvizhi *et al.* (2001) reported the increase in ESP due to repeated application of distillery effluent and it was maintained below 15. The ESP of soil was gradually increased at the end of experiment as compare to initial values. The greater ESP of soil was observed in wheat harvest 2010-11 *i.e.* at the end of experiment as compare to soybean harvest 2009-10. This was due to continuous application of PBSW to

Table 4. Effect of PBSW application through irrigation on soil pH and electrical conductivity at harvest of soybean and wheat.

Treat- ment	Soil depth (cm)	Soil pH (1:2.5)										EC (dS m ⁻¹)			
		2009-10		2010-11		2009-10		2010-11		2009-10		2010-11		Pooled mean	
		Initial	Soybean	Wheat	Soybean	Wheat	Soybean	Wheat	Initial	Soybean	Wheat	Soybean	Wheat		
T ₁	0-15	8.24	8.25 ^a	8.16 ^a	8.11 ^a	8.20 ^a	8.18 ^a	0.58	0.50 ^c	0.58 ^d	0.63 ^c	0.59 ^c	0.57 ^d		
	15-30	8.20	8.27 ^a	8.12 ^a	8.04 ^a	8.11	8.14 ^a	0.56	0.53 ^c	0.46 ^d	0.68 ^e	0.45 ^e	0.53 ^d		
	30-60	8.18	8.24 ^a	8.02 ^a	8.04	8.18	8.12 ^a	0.50	0.64 ^c	0.60 ^e	0.66 ^b	0.56 ^c	0.62 ^c		
T ₂	0-15	7.94	7.79 ^c	7.52 ^d	7.94 ^b	7.98 ^c	7.81 ^c	0.59	0.83 ^a	1.90 ^a	1.70 ^a	0.94 ^{ab}	1.34 ^a		
	15-30	7.84	7.86 ^b	7.57 ^c	7.93 ^b	8.01	7.84 ^b	0.72	1.21 ^a	1.97 ^a	1.34 ^a	1.52 ^a	1.51 ^a		
	30-60	8.00	7.90 ^b	7.78 ^c	7.98	8.02	7.91 ^c	0.60	1.35 ^a	2.58 ^a	1.29 ^a	1.37 ^a	1.65 ^a		
T ₃	0-15	8.02	7.90 ^c	7.58 ^c	7.98 ^b	8.01 ^c	7.87 ^{bc}	0.65	0.80 ^{ab}	1.70 ^a	1.21 ^b	1.01 ^a	1.18 ^{ab}		
	15-30	7.92	7.80 ^b	7.62 ^c	7.94 ^b	8.06	7.86 ^b	0.62	0.89 ^b	1.94 ^a	1.14 ^{ab}	1.25 ^b	1.31 ^{ab}		
	30-60	8.12	7.97 ^b	7.85 ^{bc}	8.04	8.07	7.99 ^b	0.54	1.160 ^a	2.34 ^b	1.24 ^a	1.41 ^a	1.54 ^a		
T ₄	0-15	7.98	7.86 ^c	7.68 ^c	8.03 ^{ab}	8.08 ^c	7.91 ^{bc}	0.62	0.74 ^{ab}	1.40 ^b	0.9 ^d	0.83 ^b	0.97 ^{bc}		
	15-30	7.81	7.90 ^b	7.72 ^{bc}	7.97 ^{ab}	8.05	7.91 ^b	0.60	0.65 ^c	1.58 ^b	0.88 ^{bc}	0.89 ^c	1.00 ^{bc}		
	30-60	8.10	7.92 ^b	7.80 ^c	8.04	8.10	7.97 ^{bc}	0.50	0.95 ^b	1.80 ^c	0.85 ^b	0.92 ^b	1.13 ^b		
T ₅	0-15	8.20	8.04 ^b	7.84 ^b	8.04 ^{ab}	8.11 ^b	8.01 ^b	0.60	0.69 ^b	1.00 ^c	0.69 ^c	0.63 ^c	0.75 ^{cd}		
	15-30	8.02	7.96 ^b	7.88 ^b	7.98 ^{ab}	8.09	7.98 ^b	0.59	0.580 ^c	1.40 ^c	0.85 ^{bc}	0.68 ^d	0.88 ^c		
	30-60	8.15	8.00 ^b	7.92 ^{ab}	8.06	8.13	8.03 ^{ab}	0.48	0.88 ^b	1.58 ^d	0.87 ^b	0.76 ^{bc}	1.03 ^b		
S.E.±	0-15	0.027	0.04	0.036	0.027	0.026	0.05	0.025	0.043	0.083	0.074	0.057	0.110		
	15-30	0.030	0.057	0.051	0.022	0.028	0.05	0.009	0.040	0.029	0.100	0.057	0.103		
	30-60	0.020	0.051	0.033	0.026	0.038	0.03	0.013	0.034	0.044	0.098	0.097	0.127		
CD (0.05)	0-15	0.082	0.147	0.112	0.083	0.079	0.14	0.035	0.133	0.254	0.228	0.175	0.339		
	15-30	0.094	0.176	0.159	0.068	NS	0.15	0.028	0.125	0.090	0.309	0.175	0.319		
	30-60	0.063	0.159	0.103	NS	NS	0.09	0.043	0.106	0.137	0.304	0.299	0.390		

Table 5. Effect of PBSW application through irrigation on soil organic carbon and calcium carbonate at harvest of soybean and wheat.

Treatment	Soil depth (cm)	Organic carbon (%)						Calcium carbonate (%)						
		2009-10			2010-11			2009-10			2010-11			
		Initial	Soybean	Wheat	Initial	Soybean	Wheat	Initial	Soybean	Wheat	Initial	Soybean	Wheat	Pooled mean
T ₁	0-15	0.69	0.62	0.63 ^a	0.61	0.53 ^b	0.60 ^{ab}	16.14	16.81 ^a	16.56 ^a	16.14	16.81 ^a	16.56 ^a	16.70 ^a
	15-30	0.64	0.54 ^a	0.52	0.59	0.51	0.54 ^a	16.75	17.50	16.75	16.75	18.00	16.10	17.09 ^a
	30-60	0.62	0.48 ^a	0.42	0.54	0.46 ^b	0.47	15.50	16.00	16.50	16.50	16.50 ^b	15.91	16.23
T ₂	0-15	0.76	0.60	0.62 ^a	0.55	0.69 ^a	0.62 ^a	15.25	15.88 ^b	14.88 ^c	15.25	15.88 ^b	16.50	15.46 ^d
	15-30	0.73	0.52 ^{ab}	0.46	0.51	0.59	0.52 ^a	15.56	16.06	15.56	15.56	16.06	15.04	15.68 ^d
	30-60	0.60	0.41 ^b	0.42	0.45	0.63 ^a	0.48	15.44	15.94	15.69	15.44	16.44 ^b	15.10	15.79
T ₃	0-15	0.79	0.53	0.56 ^{ab}	0.49	0.70 ^a	0.57 ^{ab}	15.38	15.88 ^b	15.38 ^{bc}	15.38	15.88 ^b	16.38	15.56 ^{cd}
	15-30	0.75	0.50 ^{ab}	0.47	0.47	0.62	0.51 ^{ab}	16.23	16.69	16.69	16.23	16.94	14.91	16.31 ^c
	30-60	0.65	0.43 ^{ab}	0.40	0.43	0.63 ^a	0.47	15.70	16.20	15.70	15.70	16.50 ^b	15.29	15.92
T ₄	0-15	0.73	0.50	0.50 ^b	0.47	0.55 ^b	0.51 ^c	16.25	16.63 ^{ab}	15.88 ^{abc}	16.25	16.63 ^{ab}	16.38	16.18 ^{bc}
	15-30	0.71	0.40 ^c	0.40	0.46	0.52	0.45 ^{bc}	16.50	17.25	17.25	16.50	17.50	15.54	16.88 ^{ab}
	30-60	0.62	0.39 ^b	0.37	0.42	0.43 ^b	0.40	16.13	16.88	15.88	16.13	17.88 ^a	15.23	16.46
T ₅	0-15	0.72	0.59	0.46 ^b	0.45	0.53 ^b	0.51 ^c	16.23	16.75 ^a	16.50 ^{ab}	16.23	16.75 ^a	16.50	16.45 ^{ab}
	15-30	0.70	0.43 ^{bc}	0.38	0.42	0.46	0.42 ^c	16.13	16.88	16.88	16.13	16.88	17.13	16.53 ^{bc}
	30-60	0.52	0.29 ^c	0.44	0.38	0.39 ^b	0.37	16.44	16.94	15.94	16.44	17.94 ^a	15.04	16.46
S.E.±	0-15	0.013	0.043	0.032	0.062	0.029	0.029	0.29	0.25	0.38	0.29	0.25	0.36	0.21
	15-30	0.015	0.031	0.038	0.049	0.042	0.020	0.33	0.42	0.50	0.33	0.41	0.74	0.14
	30-60	0.012	0.034	0.032	0.048	0.042	0.032	0.23	0.30	0.41	0.23	0.33	0.50	0.24
CD (0.05)	0-15	0.041	NS	0.10	NS	0.088	0.09	NS	0.76	1.16	NS	NS	NS	0.65
	15-30	0.046	0.096	NS	NS	NS	0.06	NS	NS	NS	NS	NS	NS	0.44
	30-60	0.036	0.071	NS	NS	0.128	NS	0.71	NS	NS	NS	1.02	NS	NS

soybean and wheat crop, which was responsible in increasing exchangeable Na^+ and ultimately ESP of soil.

Effect of PBSW irrigation on soil available nutrients

Available nitrogen: The highest pooled available N was recorded in treatment T_5 (188 and 177 kg ha^{-1}) and it was at par with treatment T_4 (50% N - PBSW + remaining N and P - chemical fertilizers) and T_1 in 0-15 and 15-30 cm soil depths. Among the PBSW application treatments, the lowest pooled available N was recorded in the treatments T_2 (173 and 156 kg ha^{-1}) and T_3 (171 and 160 kg ha^{-1}) and these were at par with each other at 0-15 and 15-30 cm soil depths (Table 7). The highest available nitrogen content in soil was observed in surface depth than subsurface depths. In general, the available N was steadily increased in all three soil depths and in all the treatments from 1st sampling to last sampling. The building of soil available N in all treatments was due to legume-cereal crop rotation. As the quantity of PBSW was increased, the available N content in soil was decreased in all the three soil depths. This might be due to high COD and BOD of PBSW which resulted in immobilization of available N. The high COD and BOD can increase the temperature and immobilize the nutrients particularly N as well as depletion of oxygen in soil (Kalaiselvi and Mahimairaja, 2010).

Available phosphorus: The highest pooled available P content in soil (16.21, 15.11 and 12.18 kg ha^{-1}) was recorded in treatment T_4 (50% N- PBSW and remaining N and P -chemical fertilizers) at all the soil depths. The increase in available P with PBSW application through irrigation might be due to mineralization and solubilization of native P as well as applied P through the chemical fertilizer. The treatment T_4 was at par with treatment T_5 (15.07, 13.85 and 11.62 kg ha^{-1}) at all the soil depths and treatment T_1 (13.86 and 10.05 kg ha^{-1}) at 0-15 cm and 30-60 cm soil depths. The highest availability of pooled P was observed in surface 0-15 cm soil depth than 15-30 and 30-60 cm soil depths in all the treatments (Table 8). The lowest available P was found in T_2 over the rest of other treatments during both the years of study. The increase in available P with fertigation of 25-50 % N through PBSW might be due to fast mineralization of PBSW and solubilization of native P as well as applied P through the chemical fertilizer due to release and formation of weak acid during the course of mineralization of organic matter. The available phosphorus status was significantly improved at 120 $\text{m}^3 \text{ha}^{-1}$ level of post biomethanated spentwash + RDF treatment (Deshpande *et al.*, 2011).

Available potassium: The highest pooled available K content in soil (749, 713 and 580 kg ha^{-1}) was recorded in treatment T_2 at all the soil depths. The treatment T_2 was at par with treatments T_3 (731 and 693 kg ha^{-1}) and T_4 (715 and 616 kg ha^{-1}) at 0-15 and 15-30 cm soil depths and T_3 (563 kg ha^{-1}) at 30-60 cm soil depth. The

lowest available K content in soil (555, 472 and 405 kg ha^{-1}) was noticed in the treatment where no application of PBSW was done *i.e.* RD-NPK in both the years of experimentation (Table 8). As the dose of PBSW increased there was increase in pooled soil available K in all the three soil depths tested. The high soil available K in PBSW treatments was due to the presence of high in PBSW. In addition, the high organic matter content of PBSW and its decomposition resulting in release of organic acids which might have solubilised K bearing minerals contributing to K availability. Bhosale *et al.* (2009) reported that the application of PBSW 40 $\text{m}^3 \text{ha}^{-1}$ maintained higher K fertility of soil as compared to lower levels of PBSW application and control, by maintaining higher levels of water soluble K, exchangeable K, non exchangeable K and lattice K after harvest. Higher levels of PBSW enhanced the step K and constant K realize as well as K fixing capacity of soil as compare to lower levels of PBSW and control, indicating build up of K fertility of soil.

Effect of PBSW irrigation on saturation paste extract of soil pH of saturation paste extract (pHs):

The lowest pooled pHs of soil was observed in treatment T_2 (7.64, 7.63 and 7.67) at all the soil depths as compared to other treatments. The highest pooled pHs of soil was noticed in treatment T_1 (7.95, 7.95 and 7.90) at all the soil depths as compared to rest of other treatments (Table 9). There was no drastic change in soil pHs at the end of experimentation as compare to initial values in PBSW applied treatments. The increased rate of application of PBSW proportionately decreased pHs of soil at all the soil depths as well as in pooled means in both the years of study. The reduction in the pH of saturation paste extract was also observed due to application of distillery effluent (Deshpande *et al.*, 2011).

Electrical conductivity of saturation paste extract (EC_e):

The significantly lowest pooled EC_e of soil was found in treatment T_1 (1.16, 1.39 and 1.10 dS m^{-1}) over the rest of other treatments at all the soil depths. The highest pooled EC_e of soil was recorded in treatment T_2 (3.15, 3.56 and 3.74 dS m^{-1}) at all the soil depths. However, treatments T_2 and T_3 were at par with each other at all the three soil depths tested (Table 9). The minimum salt accumulation was observed in RD-NPK followed by 25% N - PBSW + remaining N and P - chemical fertilizers during 2009-10, 2010-11 and pooled means. The gradual increase in salt concentration was found in all the PBSW treatments at all the soil depths as compare to initial soil values. This was directly related to the quantity of PBSW applied as it contains high amount of soluble salts. The EC of soil increased markedly due to accumulation of salts from spentwash (Saliha, 2003).

Sodium adsorption ratio (SAR): The significantly highest pooled SAR values of soil extract was recorded

Table 6. Effect of PBSW application through irrigation on soil CEC and exchangeable sodium at harvest of soybean and wheat.

Treat ment	Soil depth (cm)	Exchangeable sodium {cmol (p ⁺) kg ⁻¹ }																
		Soil CEC {cmol (p ⁺) kg ⁻¹ }					Exchangeable sodium {cmol (p ⁺) kg ⁻¹ }											
		2009-10		2010-11		Initial	2009-10		2010-11		Initial	2009-10		2010-11				
		Initial	Soybean	Wheat	Soybean	Wheat	Pooled mean	Initial	Soybean	Wheat	Soybean	Wheat	Pooled mean	Initial	Soybean	Wheat	Pooled mean	
T ₁	0-15	48.93	49.43 ^c	49.92 ^d	49.33 ^c	49.82 ^d	49.62 ^c	0.88	0.90 ^d	1.18 ^d	0.95 ^d	1.17 ^d	1.05 ^b					
	15-30	44.04	44.59 ^c	45.03 ^d	44.50 ^c	44.94 ^d	44.76 ^c	0.68	0.89 ^c	1.08 ^d	0.93 ^c	1.17 ^d	1.02 ^c					
	30-60	43.16	43.72 ^c	44.15 ^d	43.63 ^c	44.06 ^d	43.89 ^c	0.62	0.82 ^c	0.91 ^d	0.86 ^c	0.98 ^d	0.89 ^c					
T ₂	0-15	51.80	52.15 ^a	54.75 ^{ab}	52.04 ^a	54.64 ^{ab}	53.40 ^a	1.30	1.30 ^{ab}	1.95 ^a	2.53 ^a	3.68 ^a	2.36 ^a					
	15-30	46.62	47.03 ^a	49.38 ^{ab}	46.94 ^a	49.28 ^{ab}	48.16 ^a	1.10	1.47 ^b	2.35 ^a	2.87 ^b	3.95 ^a	2.66 ^a					
	30-60	45.68	46.11 ^a	48.41 ^{ab}	46.02 ^a	48.32 ^{ab}	47.21 ^a	0.89	1.78 ^b	1.46 ^b	3.47 ^b	4.00 ^a	2.68 ^a					
T ₃	0-15	51.40	52.10 ^a	55.67 ^a	51.99 ^a	55.56 ^a	53.83 ^a	1.34	1.35 ^a	1.66 ^b	2.64 ^a	3.24 ^b	2.22 ^a					
	15-30	46.26	46.99 ^a	50.21 ^a	46.89 ^a	50.10 ^{ab}	48.55 ^a	1.11	1.70 ^a	2.29 ^a	3.32 ^a	3.74 ^a	2.75 ^a					
	30-60	45.33	46.07 ^a	49.22 ^a	45.98 ^a	49.12 ^a	47.60 ^a	0.78	1.90 ^a	1.62 ^a	3.71 ^a	3.64 ^a	2.72 ^a					
T ₄	0-15	51.31	51.66 ^{ab}	54.19 ^b	51.55 ^{ab}	54.08 ^b	52.87 ^a	1.16	1.22 ^b	1.57 ^b	2.37 ^b	3.10 ^b	2.07 ^a					
	15-30	46.18	46.59 ^{ab}	48.87 ^b	46.50 ^{ab}	48.77 ^b	47.69 ^a	1.14	1.16 ^c	2.00 ^b	2.25 ^c	3.24 ^b	2.17 ^{ab}					
	30-60	45.25	45.68 ^{ab}	47.92 ^b	45.59 ^{ab}	47.82 ^b	46.75 ^a	0.80	1.16 ^c	1.71 ^a	2.25 ^c	3.09 ^b	2.05 ^{ab}					
T ₅	0-15	50.47	50.87 ^b	52.37 ^c	50.77 ^b	52.26 ^c	51.57 ^b	1.19	1.13 ^c	1.39 ^c	2.20 ^c	2.72 ^c	1.86 ^a					
	15-30	45.42	45.89 ^b	47.23 ^c	45.79 ^b	47.14 ^c	46.51 ^b	1.08	0.96 ^d	1.85 ^c	1.87 ^d	2.50 ^c	1.79 ^b					
	30-60	44.51	44.99 ^b	46.31 ^c	44.90 ^b	46.21 ^c	45.60 ^b	0.71	0.96 ^d	1.28 ^c	1.87 ^d	2.47 ^c	1.64 ^{bc}					
S.E.±	0-15	0.43	0.34	0.36	0.34	0.35	0.34	0.063	0.03	0.04	0.04	0.06	0.19					
	15-30	0.39	0.30	0.32	0.30	0.32	0.31	0.070	0.02	0.03	0.04	0.15	0.20					
	30-60	0.38	0.30	0.31	0.30	0.31	0.30	0.042	0.03	0.04	0.05	0.12	0.26					
CD (0.05)	0-15	1.33	1.04	1.10	1.04	1.09	1.05	0.193	0.08	0.14	0.13	0.17	0.59					
	15-30	1.20	0.94	0.99	0.94	0.98	0.95	0.216	0.06	0.09	0.12	0.45	0.62					
	30-60	1.17	0.92	0.97	0.92	0.97	0.93	0.130	0.09	0.12	0.15	0.38	0.80					

Table 7. Effect of PBSW application through irrigation on soil ESP and available N at harvest of soybean and wheat.

Treat ment	Soil depth (cm)	ESP						Available N (kg ha ⁻¹)								
		2009-10			2010-11			2009-10			2010-11					
		Initial	Soybean	Wheat	Soybean	Wheat	Initial	Soybean	Wheat	Soybean	Wheat	Soybean	Wheat	Pooled mean		
T ₁	0-15	1.79	1.82 ^d	2.37 ^d	1.92 ^d	2.35 ^d	182	170 ^c	157 ^c	2.11 ^b	182	170 ^c	157 ^c	201 ^a	199 ^{ab}	182 ^{ab}
	15-30	1.56	1.99 ^d	2.43 ^e	2.09 ^e	2.61 ^d	181	166 ^a	148 ^a	2.28 ^c	181	166 ^a	148 ^a	196 ^a	183 ^b	173 ^a
	30-60	1.43	1.87 ^e	2.07 ^d	1.97 ^e	2.23 ^e	170	97 ^a	140 ^b	2.03 ^c	170	97 ^a	140 ^b	161 ^a	172 ^c	143
T ₂	0-15	2.50	2.48 ^{ab}	3.56 ^a	5.23 ^a	6.73 ^a	195	181 ^{ab}	153 ^c	4.50 ^a	195	181 ^{ab}	153 ^c	167 ^c	190 ^c	173 ^b
	15-30	2.35	3.12 ^b	4.81 ^a	6.58 ^b	8.01 ^a	180	137 ^c	140 ^b	5.63 ^a	180	137 ^c	140 ^b	161 ^{cb}	184 ^b	156 ^b
	30-60	1.96	3.85 ^b	3.00 ^c	8.13 ^b	8.29 ^a	175	82 ^b	128 ^d	5.82 ^a	175	82 ^b	128 ^d	132 ^{bc}	178 ^{bc}	130
T ₃	0-15	2.63	2.59 ^a	2.98 ^b	5.43 ^a	5.83 ^b	198	176 ^{bc}	142 ^d	4.25 ^a	198	176 ^{bc}	142 ^d	176 ^{bc}	191 ^{bc}	171 ^b
	15-30	2.39	3.62 ^a	4.48 ^b	7.59 ^a	7.48 ^{ab}	182	149 ^b	133 ^b	5.79 ^a	182	149 ^b	133 ^b	168 ^{bc}	189 ^{ab}	160 ^b
	30-60	1.71	4.12 ^a	3.30 ^b	8.64 ^a	7.40 ^b	174	95 ^a	121 ^e	5.87 ^a	174	95 ^a	121 ^e	134 ^b	177 ^{bc}	132
T ₄	0-15	2.27	2.35 ^{bc}	2.90 ^{bc}	4.61 ^b	5.73 ^b	204	178 ^b	167 ^b	3.85 ^a	204	178 ^b	167 ^b	195 ^{ab}	201 ^a	188 ^a
	15-30	2.46	2.47 ^c	4.14 ^c	4.84 ^c	6.65 ^b	186	165 ^a	150 ^a	4.53 ^a	186	165 ^a	150 ^a	188 ^{ab}	190 ^{ab}	173 ^a
	30-60	1.75	2.52 ^c	3.57 ^a	4.94 ^c	6.46 ^c	186	91 ^a	132 ^c	4.37 ^{ab}	186	91 ^a	132 ^c	148 ^{ab}	191 ^a	141
T ₅	0-15	2.34	2.22 ^c	2.65 ^c	4.23 ^c	5.21 ^c	200	188 ^a	176 ^a	3.47 ^a	200	188 ^a	176 ^a	199 ^a	197 ^{abc}	188 ^a
	15-30	2.38	2.08 ^d	3.90 ^d	3.97 ^d	5.31 ^c	185	172 ^a	155 ^a	3.82 ^b	185	172 ^a	155 ^a	186 ^{ab}	195 ^a	177 ^a
	30-60	1.59	2.12 ^d	2.77 ^c	4.05 ^d	5.34 ^d	172	94 ^a	148 ^a	3.57 ^{bc}	172	94 ^a	148 ^a	154 ^a	183 ^{ab}	145
S.E.±	0-15	0.05	0.05	0.08	0.09	0.11	2.22	2.44	2.78	0.37	2.22	2.44	2.78	7.355	2.718	4.26
	15-30	0.10	0.05	0.06	0.10	0.31	3.87	3.33	2.37	0.44	3.87	3.33	2.37	7.580	2.555	3.63
	30-60	0.11	0.07	0.08	0.12	0.24	2.068	2.73	1.19	0.60	2.068	2.73	1.19	5.896	3.287	3.88
CD (0.05)	0-15	0.15	0.16	0.26	0.27	0.33	9.006	7.52	8.57	1.14	9.006	7.52	8.57	22.67	8.381	13.14
	15-30	0.30	0.17	0.20	0.32	0.95	NS	10.27	7.32	1.37	NS	10.27	7.32	23.36	7.877	11.19
	30-60	0.33	0.22	0.26	0.38	0.73	6.373	8.42	3.69	1.86	6.373	8.42	3.69	18.17	10.13	NS

Table 8. Effect of PBSW application through irrigation on soil available P and K at harvest of soybean and wheat.

Treat ment	Soil depth (cm)	Available P (kg ha ⁻¹)										Available K (kg ha ⁻¹)									
		2009-10			2010-11			2009-10			2010-11			2009-10			2010-11				
		Initial	Soybean	Wheat	Soybean	Wheat	Soybean	Wheat	Pooled mean	Initial	Soybean	Wheat	Soybean	Wheat	Pooled mean	Initial	Soybean	Wheat	Soybean	Wheat	Pooled mean
T ₁	0-15	13.24	11.82 ^c	16.10 ^c	12.46 ^a	15.04 ^{ab}	13.86 ^{ab}	570	597 ^b	561 ^c	597 ^b	561 ^c	597 ^b	555 ^c	570	597 ^b	561 ^c	597 ^b	561 ^c	467 ^c	555 ^c
	15-30	12.8	7.54 ^d	14.50 ^c	10.97 ^a	12.66 ^{bc}	11.42 ^{bc}	520	540 ^c	433 ^c	540 ^c	433 ^c	527 ^b	472 ^c	520	540 ^c	433 ^c	527 ^b	433 ^c	389 ^d	472 ^c
	30-60	11.8	5.98 ^a	12.71 ^c	9.47 ^a	12.03 ^{bc}	10.05 ^{ab}	460	366 ^c	400 ^d	366 ^c	400 ^d	493 ^a	405 ^c	460	366 ^c	400 ^d	493 ^a	400 ^d	361 ^c	405 ^c
T ₂	0-15	16.1	10.26 ^d	10.00 ^c	8.40 ^c	10.75 ^b	9.85 ^c	840	644 ^{ab}	740 ^a	644 ^{ab}	740 ^a	749 ^a	840	644 ^{ab}	740 ^a	740 ^a	787 ^a	740 ^a	823 ^a	749 ^a
	15-30	15.8	7.90 ^c	8.20 ^c	6.76 ^{cd}	8.30 ^d	7.79 ^d	693	621 ^a	784 ^a	621 ^a	784 ^a	713 ^a	693	621 ^a	784 ^a	655 ^a	655 ^a	790 ^a	790 ^a	713 ^a
	30-60	12.5	5.30 ^b	5.62 ^c	5.77 ^c	8.61 ^c	6.33 ^c	590	560 ^a	672 ^a	560 ^a	672 ^a	580 ^a	590	560 ^a	672 ^a	490 ^a	490 ^a	597 ^a	597 ^a	580 ^a
T ₃	0-15	18.8	9.69 ^e	13.10 ^d	9.23 ^{bc}	13.95 ^{ab}	11.49 ^{bc}	804	621 ^{ab}	726 ^a	621 ^{ab}	726 ^a	731 ^a	804	621 ^{ab}	726 ^a	761 ^a	761 ^a	815 ^a	815 ^a	731 ^a
	15-30	15.6	7.26 ^e	10.50 ^d	8.33 ^{bc}	11.40 ^{cd}	9.37 ^{cd}	692	599 ^b	790 ^a	599 ^b	790 ^a	693 ^a	692	599 ^b	790 ^a	655 ^a	499 ^a	588 ^a	728 ^{ab}	693 ^a
	30-60	12.2	4.20 ^c	9.12 ^d	6.76 ^{bc}	10.40 ^c	7.62 ^{bc}	590	534 ^a	629 ^b	534 ^a	629 ^b	563 ^{ab}	590	534 ^a	629 ^b	499 ^a	499 ^a	588 ^a	588 ^a	563 ^{ab}
T ₄	0-15	16.8	12.73 ^a	22.71 ^a	9.79 ^{bc}	19.74 ^a	16.21 ^a	780	784 ^a	678 ^b	784 ^a	678 ^b	715 ^{ab}	780	784 ^a	678 ^b	631 ^b	631 ^b	767 ^a	767 ^a	715 ^{ab}
	15-30	15.9	11.89 ^a	20.10 ^a	9.44 ^{ab}	18.88 ^a	15.11 ^a	620	582 ^b	690 ^b	582 ^b	690 ^b	616 ^{ab}	620	582 ^b	690 ^b	526 ^b	526 ^b	664 ^{bc}	664 ^{bc}	616 ^{ab}
	30-60	10.7	5.10 ^b	18.54 ^a	8.12 ^{ab}	16.96 ^a	12.18 ^a	580	445 ^b	447 ^c	445 ^b	447 ^c	470 ^{bc}	580	445 ^b	447 ^c	433 ^{ab}	433 ^{ab}	557 ^{ab}	557 ^{ab}	470 ^{bc}
T ₅	0-15	14.0	11.96 ^b	20.12 ^b	10.31 ^b	17.90 ^a	15.07 ^a	668	506 ^b	671 ^b	506 ^b	671 ^b	597 ^{bc}	668	506 ^b	671 ^b	556 ^b	556 ^b	655 ^b	655 ^b	597 ^{bc}
	15-30	13.6	9.02 ^b	18.90 ^b	11.07 ^a	16.40 ^{ab}	13.85 ^{ab}	575	504 ^d	677 ^b	504 ^d	677 ^b	553 ^{bc}	575	504 ^d	677 ^b	426 ^c	426 ^c	605 ^c	605 ^c	553 ^{bc}
	30-60	11.2	6.00 ^a	16.00 ^b	8.87 ^{ab}	15.60 ^{ab}	11.62 ^a	467	361 ^c	446 ^c	361 ^c	446 ^c	431 ^c	467	361 ^c	446 ^c	385 ^b	385 ^b	532 ^b	532 ^b	431 ^c
SE _±	0-15	0.685	0.03	0.02	0.59	1.91	1.12	12.76	59.13	10.28	59.13	10.28	38.11	12.76	59.13	10.28	46.25	46.25	23.06	23.06	38.11
	15-30	0.302	0.03	0.03	0.85	1.39	1.10	8.84	6.85	6.38	6.85	6.38	37.42	8.84	6.85	6.38	22.68	22.68	39.61	39.61	37.42
	30-60	0.243	0.22	0.04	0.69	1.31	1.17	6.74	8.90	7.74	8.90	7.74	30.14	6.74	8.90	7.74	31.77	31.77	17.37	17.37	30.14
CD (0.05)	0-15	2.112	0.09	0.06	1.83	5.89	3.45	39.36	182.22	31.69	182.22	31.69	117.50	39.36	182.22	31.69	142.60	142.60	71.10	71.10	117.50
	15-30	0.931	0.09	0.10	2.61	4.29	3.38	27.25	21.12	20.61	21.12	20.61	115.37	27.25	21.12	20.61	69.93	69.93	122.12	122.12	115.37
	30-60	0.749	0.69	0.13	2.13	4.05	3.61	20.78	27.43	23.86	27.43	23.86	92.91	20.78	27.43	23.86	97.94	97.94	53.55	53.55	92.91

Table 9. Effect of PBSW application through irrigation on pHs and ECe of saturation paste extract of soil at harvest of soybean and wheat.

Treat ment	Soil depth (cm)	pHs												ECe (dS m ⁻¹)			
		2009-10				2010-11				2009-10				2010-11			
		Initial	Soybean	Wheat	Pooled mean	Initial	Soybean	Wheat	Pooled mean	Initial	Soybean	Wheat	Pooled mean	Initial	Soybean	Wheat	Pooled mean
T ₁	0-15	7.86	7.92 ^a	7.96 ^a	7.93	7.95 ^a	7.93	7.95 ^a	0.95	1.00 ^d	1.67 ^c	1.12 ^c	0.86 ^c	1.16 ^d	1.39 ^c	1.10 ^c	1.16 ^d
	15-30	7.87	8.07 ^a	7.79 ^a	7.91 ^a	7.95 ^a	7.91 ^a	7.95 ^a	0.90	0.95 ^c	2.16 ^d	1.18 ^c	1.26 ^c	1.39 ^c	1.39 ^c	1.10 ^c	1.39 ^c
	30-60	7.99	7.96 ^a	7.76 ^a	7.92	7.90 ^a	7.92	7.90 ^a	0.84	0.89 ^d	0.85 ^d	1.33 ^d	1.34 ^c	1.10 ^c	1.10 ^c	1.10 ^c	1.10 ^c
T ₂	0-15	7.48	7.49 ^c	7.40 ^{cd}	7.79	7.64 ^c	7.89	7.64 ^c	3.94	3.21 ^a	3.87 ^a	2.58 ^a	2.93 ^a	3.15 ^a	3.15 ^a	3.15 ^a	3.15 ^a
	15-30	7.37	7.42 ^c	7.43 ^{bc}	7.86	7.63 ^c	7.79 ^b	7.63 ^c	3.27	3.47 ^a	4.37 ^a	2.73 ^a	3.70 ^a	3.56 ^a	3.56 ^a	3.56 ^a	3.56 ^a
	30-60	7.57	7.51 ^b	7.52 ^b	7.90	7.67 ^c	7.74	7.67 ^c	2.88	3.03 ^a	4.25 ^a	3.52 ^{ab}	4.15 ^a	3.74 ^a	3.74 ^a	3.74 ^a	3.74 ^a
T ₃	0-15	7.50	7.55 ^c	7.38 ^d	7.87	7.65 ^c	7.80	7.65 ^c	3.60	3.04 ^{ab}	3.80 ^a	2.51 ^a	2.84 ^a	3.05 ^a	3.05 ^a	3.05 ^a	3.05 ^a
	15-30	7.50	7.53 ^c	7.29 ^c	8.00	7.64 ^{bc}	7.75 ^b	7.64 ^{bc}	3.00	3.16 ^a	4.13 ^a	2.92 ^a	3.46 ^a	3.42 ^a	3.42 ^a	3.42 ^a	3.42 ^a
	30-60	7.60	7.58 ^b	7.45 ^b	7.87	7.67 ^c	7.77	7.67 ^c	2.78	2.92 ^a	4.12 ^a	3.63 ^a	3.85 ^a	3.63 ^a	3.63 ^a	3.63 ^a	3.63 ^a
T ₄	0-15	7.52	7.61 ^b	7.58 ^{bc}	7.92	7.76 ^b	7.92	7.76 ^b	2.33	2.38 ^{bc}	2.74 ^b	1.63 ^b	2.04 ^b	2.20 ^b	2.20 ^b	2.20 ^b	2.20 ^b
	15-30	7.41	7.46 ^c	7.47 ^b	7.93	7.65 ^b	7.74 ^b	7.65 ^b	1.90	2.00 ^b	3.49 ^b	2.03 ^b	3.21 ^b	2.68 ^b	2.68 ^b	2.68 ^b	2.68 ^b
	30-60	7.75	7.64 ^b	7.51 ^b	7.93	7.72 ^{bc}	7.80	7.72 ^{bc}	2.02	1.96 ^b	2.47 ^c	3.14 ^{bc}	2.74 ^b	2.58 ^b	2.58 ^b	2.58 ^b	2.58 ^b
T ₅	0-15	7.81	7.87 ^a	7.63 ^b	7.96	7.85 ^{ab}	7.95	7.85 ^{ab}	1.90	2.01 ^c	1.91 ^c	1.41 ^b	1.88 ^b	1.80 ^c	1.80 ^c	1.80 ^c	1.80 ^c
	15-30	7.81	7.82 ^b	7.59 ^b	7.96	7.79 ^{ab}	7.81 ^{ab}	7.79 ^{ab}	1.67	1.76 ^b	2.90 ^c	1.78 ^b	2.59 ^b	2.26 ^b	2.26 ^b	2.26 ^b	2.26 ^b
	30-60	7.89	7.88 ^a	7.61 ^{ab}	7.98	7.83 ^{ab}	7.84	7.83 ^{ab}	1.47	1.54 ^c	2.53 ^b	2.77 ^c	2.25 ^b	2.27 ^b	2.27 ^b	2.27 ^b	2.27 ^b
S.E.±	0-15	0.05	0.04	0.06	0.05	0.05	0.05	0.05	0.18	0.23	0.20	0.09	0.19	0.12	0.12	0.12	0.12
	15-30	0.04	0.05	0.06	0.04	0.06	0.04	0.06	0.09	0.10	0.18	0.18	0.21	0.12	0.12	0.12	0.12
	30-60	0.06	0.05	0.05	0.05	0.04	0.05	0.04	0.14	0.11	0.17	0.12	0.22	0.16	0.16	0.16	0.16
CD (0.05)	0-15	0.16	0.13	0.19	NS	0.16	NS	0.16	0.57	0.72	0.62	0.27	0.51	0.36	0.36	0.36	0.36
	15-30	0.14	0.16	0.17	NS	0.19	NS	0.19	0.29	0.31	0.54	0.54	0.64	0.37	0.37	0.37	0.37
	30-60	0.19	0.14	0.16	NS	0.12	NS	0.12	0.43	0.33	0.53	0.38	0.69	0.49	0.49	0.49	0.49

Table 10. Effect of PBSW application through irrigation on SAR in saturation paste extract of soil at harvest of soybean and wheat.

Treatment	Soil depth (cm)	SAR (m mol L ⁻¹) ^{1/2}					Pooled mean
		2009-10			2010-11		
		Initial	Soybean	Wheat	Soybean	Wheat	
T ₁	0-15	1.21	1.27 ^c	1.37 ^c	0.98 ^{bc}	1.40	1.25 ^b
	15-30	0.88	0.90 ^b	1.63	1.35 ^b	1.43 ^c	1.33 ^c
	30-60	1.02	1.02 ^c	1.55	1.49 ^c	1.50 ^d	1.39 ^c
T ₂	0-15	2.62	2.78 ^a	1.84 ^a	1.74 ^a	1.77	2.03 ^a
	15-30	2.34	2.24 ^a	1.74	2.05 ^a	2.72 ^a	2.19 ^a
	30-60	1.50	1.54 ^{ab}	1.62	2.67 ^a	3.10 ^a	2.23 ^a
T ₃	0-15	2.72	2.82 ^a	1.71 ^{ab}	1.71 ^a	1.73	1.99 ^a
	15-30	2.26	2.25 ^a	1.60	1.93 ^a	2.33 ^{ab}	2.03 ^a
	30-60	1.60	1.62 ^a	1.53	2.62 ^a	2.80 ^a	2.14 ^{ab}
T ₄	0-15	2.04	2.11 ^b	1.42 ^c	1.25 ^b	1.38	1.54 ^b
	15-30	1.92	1.88 ^a	1.68	1.35 ^b	2.16 ^{ab}	1.77 ^{ab}
	30-60	1.09	1.07 ^{bc}	1.50	2.06 ^b	2.26 ^{ab}	1.72 ^{bc}
T ₅	0-15	1.90	1.95 ^b	1.45 ^{bc}	0.93 ^c	1.32	1.41 ^b
	15-30	1.26	1.23 ^b	1.58	1.27 ^b	1.82 ^{bc}	1.48 ^{bc}
	30-60	1.04	1.02 ^c	1.54	2.00 ^b	2.12 ^{ab}	1.67 ^c
S.E.±	0-15	0.11	0.13	0.09	0.09	0.16	0.12
	15-30	0.15	0.15	0.08	0.13	0.19	0.14
	30-60	0.15	0.16	0.08	0.12	0.41	0.14
CD (0.05)	0-15	0.34	0.39	0.28	0.28	NS	0.36
	15-30	0.46	0.46	NS	0.39	0.59	0.43
	30-60	0.48	0.49	NS	0.36	1.25	0.42

in treatment T₂ (2.03, 2.19 and 2.23) at all the soil depths over the rest of other treatments and it was at par with treatments T₃ (1.99, 2.03 and 2.14) at all the soil depths and T₄ (1.77) at 15-30 cm soil depth. The lowest pooled SAR values of soil extract was observed in treatment T₁ (1.25, 1.33 and 1.39) over the rest of other treatments at all the soil depths and it was at par with treatments T₅ (1.41, 1.48 and 1.67) at all the soil depths and with T₄ (1.54 and 1.72) at 0-15 and 30-60 cm soil depths (Table 10). It was clearly indicated that the increase in PBSW application through irrigation increased SAR values of soil extract. The increase in SAR values as increase in quantity PBSW application through irrigation was due to higher soluble Na⁺ concentration present in PBSW in both the years of study and SAR values of soil extract in all the three soil depths were gradually increased at the end of experiment as compare to initial soil values. The PBSW also contain high amount of colloidal organic matter which decomposes easily and thereby increase physical properties of surface soil, due to which there was leaching of Na⁺ from surface layer to 15-30 and 30-60 cm soil layer. This leaching of Na⁺ in lower layers was responsible for increasing SAR of lower

layers. In the case of vertisol and alfisol, Murugaragavan (2002) observed increase in SAR and ESP due to application of spentwash. However, these values (SAR <3.62; ESP <4.8) were well below the threshold levels, suggesting even at higher rate the spentwash application is unlikely to cause any sodicity problem in these soils.

Effect of PBSW irrigation on microbial properties of soil: The higher bacterial, fungal and actinomycetes population were observed in treatment T₃ and followed by treatment T₂ in pooled mean and two years of the experimentation. This might be due to the high organic carbon content in PBSW also helped in increasing bacterial population as well as different levels of PBSW (Table 11). Mallika *et al.*, (2003) reported that the microbial population increased upto flowering stage and thereafter it decreased. The high organic carbon content of PBSW serves as food and energy for soil microorganisms. The microbial populations (bacteria, fungi, actinomycetes, azotobacter, and phosphate-solubilizing bacteria) increased with an increase in the levels of application of PBSW (Deshpande *et al.*, 2012). However, the lowest bacterial, fungal and actinomycetes population was

Table 11. Effect of PBSW application through irrigation on microbial population at harvest of soybean and wheat (0-15 cm soil depth).

Treatment	Bacterial population ($\times 10^5$ CFU g^{-1})					Pooled Mean
	2009-10		2010-11			
	Initial	Soybean	Wheat	Soybean		
T ₁	8.75	9.51 ^c	9.50	9.75 ^b	8.75	9.38 ^b
T ₂	12.25	13.00 ^{ab}	13.00	12.00 ^a	11.50	12.38 ^a
T ₃	12.50	14.00 ^a	12.50	12.75 ^a	11.00	12.56 ^a
T ₄	9.62	10.75 ^{abc}	10.38	9.25 ^b	9.50	9.97 ^b
T ₅	9.12	9.62 ^{bc}	10.00	9.37 ^b	9.25	9.56 ^b
S.E. \pm	0.914	1.09	1.070	0.67	0.898	0.26
CD (0.05)	2.819	3.38	NS	2.07	NS	0.81
Fungal population ($\times 10^5$ CFU g^{-1})						
T ₁	3.10	3.15 ^b	3.40 ^c	3.08 ^c	3.20 ^b	3.21 ^c
T ₂	4.05	4.15 ^a	5.11 ^a	3.95 ^a	4.60 ^a	4.45 ^a
T ₃	4.22	4.38 ^a	5.08 ^a	4.05 ^a	4.50 ^a	4.50 ^a
T ₄	3.22	3.30 ^b	4.53 ^b	3.43 ^b	4.48 ^a	3.94 ^b
T ₅	3.15	3.20 ^b	4.31 ^b	3.28 ^b	4.45 ^a	3.81 ^b
S.E. \pm	0.098	0.139	0.128	0.108	0.104	0.14
CD (0.05)	0.303	0.430	0.396	0.334	0.321	0.43
Actinomycetes population ($\times 10^5$ CFU g^{-1})						
T ₁	2.32	2.48 ^c	2.38 ^d	2.35 ^c	2.35 ^d	2.39 ^e
T ₂	3.05	3.43 ^a	3.23 ^{ab}	3.28 ^a	3.10 ^{ab}	3.26 ^b
T ₃	3.32	3.58 ^a	3.48 ^a	3.35 ^a	3.28 ^a	3.42 ^a
T ₄	2.70	2.95 ^b	3.00 ^{bc}	2.78 ^b	2.85 ^{bc}	2.90 ^c
T ₅	2.50	2.80 ^{bc}	2.78 ^c	2.73 ^b	2.73 ^c	2.76 ^d
S.E. \pm	0.11	0.105	0.094	0.105	0.106	0.03
CD (0.05)	0.33	0.324	0.291	0.324	0.325	0.10

observed in RD-NPK in both the years of experimentation.

Effect of PBSW irrigation on uptake of NPK: The highest total uptake of N and P by cropping sequence was noticed in 25 % RD of N - PBSW + remaining N and P through chemical fertilizers (Table 12) and total uptake of K in RD-NPK over the rest of other treatments (Table 12). The treatments RD-NPK and 25 % RD of N -PBSW + remaining N and P through chemical fertilizers were at par with each other for total uptake of N, P and K by cropping sequence. Increased PBSW application proportionately, decreased the total N, P and K uptake by soybean and wheat crop during both the years of experimentation (Table 12). The increased total uptake

of N P and K by soybean and wheat was found in 25 and 50 % N-PBSW + remaining N and P-chemical fertilizers. This might be due to more solubility of chemical fertilizers as well as fast mineralization of PBSW applied in small quantity which increased the availability of nutrients, ultimately increased yield and uptake of nutrients. Sukanya and Meli (2004) indicated that the total nutrient uptake by wheat was significantly higher at 1:50 dilution level as it effected maximum biomass and economic yield.

Effect of PBSW irrigation on Yield

Grain and straw yield of soybean: The treatment T₁ (3.83 q ha⁻¹) recorded highest grain yield of soybean and it was at par with T₅ (3.44 q ha⁻¹). Whereas, the treatment T₅ (25 % N - PBSW + remaining N and P

Table 12. Effect of PBSW application through irrigation on total N, P, and K uptake by soybean and wheat.

Treatment	N uptake (kg ha ⁻¹)						Total nitrogen uptake of cropping sequence
	Soybean			Wheat			
	2009-10	2010-11	Total	2009-10	2010-11	Total	
T ₁	32.38 ^a	59.03 ^b	91.41 ^a	79.25 ^a	102.69 ^{ab}	181.94 ^a	273.45 ^a
T ₂	15.91 ^c	28.23 ^d	44.14 ^d	33.75 ^d	40.22 ^d	73.97 ^d	118.11 ^d
T ₃	23.67 ^c	36.87 ^c	60.54 ^c	36.78 ^d	53.61 ^c	90.39 ^c	150.93 ^c
T ₄	27.93 ^b	55.84 ^b	83.79 ^b	63.20 ^c	92.61 ^b	155.81 ^b	239.06 ^b
T ₅	30.06 ^a	67.90 ^a	97.96 ^a	71.73 ^b	106.86 ^a	178.59 ^a	276.55 ^a
S.E.±	0.83	1.75	2.19	1.57	3.82	4.27	3.32
CD (0.05)	2.56	5.39	6.75	4.84	11.77	13.17	10.25
P uptake (kg ha⁻¹)							
T ₁	8.97 ^a	10.04 ^b	19.01 ^a	22.61 ^a	27.33 ^a	49.96 ^a	68.95 ^a
T ₂	3.32 ^e	4.60 ^e	7.92 ^d	9.46 ^c	11.62 ^d	21.08 ^d	29.00 ^d
T ₃	5.85 ^d	6.13 ^d	11.98 ^c	10.30 ^c	15.22 ^c	25.52 ^c	37.50 ^c
T ₄	7.42 ^c	9.37 ^c	16.79 ^b	19.02 ^b	23.65 ^b	42.67 ^b	59.46 ^b
T ₅	8.47 ^b	11.10 ^a	19.56 ^a	21.42 ^a	26.28 ^a	47.70 ^a	67.26 ^a
S.E.±	0.12	0.20	0.18	0.51	0.85	1.13	1.22
CD (0.05)	0.36	0.64	0.55	1.56	2.64	3.51	3.76
K uptake (kg ha⁻¹)							
T ₁	30.55 ^a	35.08 ^b	65.63 ^b	69.29 ^a	68.39 ^a	137.69 ^a	203.31 ^a
T ₂	13.67 ^c	19.11 ^d	32.78 ^d	36.38 ^d	42.20 ^b	78.58 ^c	111.36 ^d
T ₃	18.20 ^b	22.85 ^c	41.05 ^c	37.36 ^d	44.86 ^b	82.23 ^c	123.30 ^c
T ₄	27.90 ^a	34.88 ^b	62.79 ^b	58.81 ^c	66.52 ^a	125.33 ^b	188.12 ^b
T ₅	31.25 ^a	41.45 ^a	72.72 ^a	65.19 ^b	66.47 ^a	131.66 ^{ab}	204.38 ^a
S.E.±	1.13	0.89	1.24	1.28	2.07	2.38	2.90
CD (0.05)	3.48	2.76	3.85	3.95	6.42	7.34	8.95

Table 13. Effect of PBSW application through irrigation on grain and straw yield of soybean and wheat.

Treatment	Soybean grain yield (q ha ⁻¹)			Soybean straw yield (q ha ⁻¹)		
	2009-10	2010-11	Pooled mean	2009-10	2010-11	Pooled mean
T ₁	3.83 ^a	8.02 ^b	5.93	15.02 ^a	19.94 ^a	17.48
T ₂	1.98 ^c	4.39 ^d	3.19	6.93 ^b	10.50 ^b	8.72
T ₃	2.35 ^c	5.73 ^c	4.04	13.80 ^a	12.14 ^b	12.97
T ₄	3.03 ^b	7.99 ^b	5.51	13.42 ^a	17.57 ^a	15.50
T ₅	3.44 ^{ab}	9.46 ^a	6.45	15.45 ^a	20.39 ^a	17.92
S.E.±	0.19	0.35	0.40	1.23	0.84	1.13
CD (0.05)	0.59	1.08	NS	3.81	2.59	NS

Treatment	Wheat grain yield (q ha ⁻¹)			Wheat straw yield (q ha ⁻¹)		
	2009-10	2010-11	Pooled mean	2009-10	2010-11	Pooled mean
T ₁	33.19 ^a	40.64 ^a	36.92 ^a	43.82 ^a	56.62 ^a	50.22 ^a
T ₂	14.64 ^c	19.92 ^c	17.28 ^d	22.14 ^c	35.45 ^b	28.80 ^b
T ₃	15.84 ^c	25.70 ^c	20.77 ^c	22.87 ^c	37.15 ^b	30.01 ^b
T ₄	27.80 ^b	34.47 ^b	31.14 ^b	33.47 ^b	55.23 ^a	44.35 ^a
T ₅	29.55 ^b	37.61 ^{ab}	33.58 ^b	40.96 ^a	57.35 ^a	49.16 ^a
S.E.±	1.17	1.98	1.01	2.01	2.63	2.23
CD (0.05)	3.60	6.11	3.12	6.20	8.12	6.71

through chemical fertilizers) was at par with T₁ and T₄ (3.03 q ha⁻¹) and the T₂ (1.98 q ha⁻¹) treatment showed lowest grain yield of soybean during the year 2009-10, which was at par with T₃ (2.35 q ha⁻¹). During 2010-11, the treatment T₅ (9.46 q ha⁻¹) had given significantly highest yield of soybean grain, next to that T₁ (8.02 q ha⁻¹) yielded more which was statistically at par with T₄ (7.99 q ha⁻¹). The treatment T₂ (4.39 q ha⁻¹) significantly yielded lowest soybean grain during 2010-11. The statistically differences in pooled grain yield of soybean was non significant (Table 13). However, the similar trend of straw yield of soybean was observed as per grain yield. The RD-NPK was at par with 25 % RD of N through PBSW + remaining N and P - chemical fertilizers for grain yield of soybean during the year 2009-10. It clearly indicated that 25 % N fertilizer could be saved by application of PBSW. This might be due to mineralization of organic matter of PBSW and during the mineralization process more availability of nutrients including micronutrients to soybean. Bhosale *et al.*, (2009) reported that the grain and straw yields of soybean were significantly increased over control due to application of various levels of PBSW. The grain yield of soybean at all the levels of PBSW was found significantly superior over control. However, due to uncertainty in rains during *kharif*, PBSW application through irrigation to soybean can become questionable and hence cannot be recommended.

Grain and straw yield of wheat: The significantly highest pooled grain yield of wheat was recorded in treatment T₁ (36.92 q ha⁻¹). Among the PBSW treatments, the highest pooled grain yield of wheat

(33.58 q ha⁻¹) was recorded in treatment T₅ and it was at par with T₄ (31.14 q ha⁻¹). The lowest grain yield of wheat was obtained in treatment T₂ (100% N - PBSW + without P chemical fertilizer) during both the years of experimentation and in pooled means (14.64, 19.92 and 17.28 q ha⁻¹, respectively). The similar trend was observed in straw yield of wheat (Table 13). The increasing grain and straw yield of wheat in 25 and 50% RD of N through PBSW and remaining N and P through chemical fertilizers treatments was undergone speedy decomposition due to high amount of chemical N through fertilizers, which was helpful for increasing soil available nitrogen rather than immobilization as seen in 100 % N-PBSW treatments. The salt load added through 25 or 50 % N-PBSW treatments was also low as compare to 100 % N-PBSW, which was tolerated by the wheat, due to its well known tolerance nature against salt (Maas and Hoffman, 1977). The other beneficial aspects of PBSW, as it contains micronutrients, plant growth hormones were also helpful for wheat growth at lower salt concentration level (Zalawadia *et al.*, 1997 and Rajukkannu and Manickam, 1997).

Effect of PBSW irrigation on economics of soybean and wheat: The gross returns, net returns and B: C ratio of soybean and wheat was highest in treatment T₁ (Rs. 59969 ha⁻¹, Rs. 18540 ha⁻¹ and 1.44) in the year 2009-10. During the year 2010-11, the highest gross returns and net returns of soybean and wheat was recorded in treatment T₁ (Rs. 76433 ha⁻¹ and Rs. 35579 ha⁻¹) and B: C ratio in treatment T₅ (1.96). The lowest mean of gross returns, net returns and B: C ratio of

soybean and wheat was recorded in treatment T₂ in both the years of experimentation. The highest mean of B: C ratio of soybean and wheat was observed in treatment T₅ and followed by T₁. This might be due to higher grain yield of soybean and wheat crop was obtained in these treatments as compared to other treatments. Balasubramaniam *et al.* (2013) reported that the B: C ratio of 1.82 was recorded by the addition of treated sugarcane distillery effluent @ 40,000 l ha⁻¹ with 100 per cent NPK which was on par with the application of treated sugarcane distillery effluent @ 40,000 l ha⁻¹ with 75 per cent NPK.

Conclusion

Looking to the high BOD, COD, high salt load of PBSW and soil properties, it can be concluded that the 25% recommended dose of N through PBSW application through irrigation and remaining N and P through chemical fertilizers to soybean and wheat crop was improvement in physical, chemical and microbial soil properties as compared to RD-NPK at all three soil depths. The 25 % N-recommended dose can be replaced by PBSW for soybean and wheat crop in sequence without disturbing soils by salt load. The PBSW application through irrigation in two equal splits at 2nd and 3rd irrigation for soybean and three equal splits at 3rd, 4th and 5th irrigation for wheat is recommended. The remaining recommended N and P dose should be supplied through chemical fertilizers. As the PBSW contain high amount of K, potassium fertilizers should not be added separately.

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