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Research Paper

Effect of cow-based bio-enhancers and botanicals on yield, yield attributes and economics of soybean (*Glycine max*) and their residual effect on wheat (*Triticum aestivum*)

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ABSTRACT

A field experiment was conducted during 2018–19 and 2019–20 at Instructional Farm, Junagadh Agricultural University, Junagadh, Gujarat, to study the effect of cow based bio-enhancers and botanicals on productivity and profitability of soybean [*Glycine max*. (L.) Merr.] and their residual effect on wheat (*Triticum aestivum* L.). The experiment was laid out in randomized-block design with 12 treatment combinations of compost, botanicals and bio-enhancers, including 100% recommended dose of fertilizer (RDF) and replicated thrice. Significantly highest number of pods/plant (59.33), seeds/pod (3.83), test weight (14.77), seed yield (2.50 t/ha), stover yield (3.08 t/ha) and harvest index (44.8%) of soybean were recorded with application of 100% RDF, i.e. 30, 60 and 0 kg N, P and K/ha, followed by application of vermicompost @ 4 t/ha and application of farmyard manure @ 10 t/ha. Similarly, findings of wheat experiment under residual fertility revealed that, the significantly highest spikelets/spike (13.17), grains/spike (34.33), 1,000-grain volume (42.83 ml), 1,000-grains weight (50.83 g), grain yield (3.90 t/ha) and straw yield (6.95 t/ha) of wheat were recorded with application vermicompost @ 4 t/ha followed by FYM @ 10 t/ha and vermicompost @ 2 t/ha + *Panchgavya* @ 3% as foliar spray at 30 and 60 days after sowing (DAS). The highest net profit (₹129,694/ha) and benefit : cost ration (4.53) were recorded with application of FYM @ 5 t/ha + *Panchgavya* @ 3% as foliar spray at 30 and 60 DAS.

Key words: Bio-enhancers, FYM, Seaweed extract, Soybean, Vermicompost, Wheat

Soybean [Glycine max (L.) Merr.] is the major oilseed crop and contributes more than half of the production among oilseeds and covers 14% of the gross cropped area in the country. Soybean performance as a rainy-season crop in the many Indian states makes it most valuable and commercial crop among the entire oilseed (Morgan *et al.*, 2003). India is the fifth largest producer of soybean with 10.47 million hectare area (DoA, Gujarat, 2018). Soybean followed by wheat is a one of the most dominating cropping system in Central parts of India, i.e. 4.5 million ha. Soybean protein is rich in amino acids like lysine, leucine, methionine and threonine. Soybean meal contributes as a feeds for poultry and fish. Being a leguminous crop, it improves soil fertility by fixing atmospheric nitrogen (50–60 kg/ha) which further improves soil physical, chemical and biological properties (Meena *et al*., 2013). Wheat (*Triticum aestivum* L.) is staple food all over the world and consists 30 million ha area with 93.51 million tonnes of production. It contains highest protein (10–12%) among the cereals and also rich in niacin and thiamine. Besides, their significance in nutrition, they are principally concerned in providing characteristic substance gluten.

Reduction in foodgrain production is mainly attributes to imbalanced application of inorganic fertilizer, delay in onset of monsoon and lack of irrigation facilities. With the advancement, excess use of inorganic fertilizer results in poor soil physical, chemical and biological conditions. Adoption of organic farming practices such as use of bio-enhancers, botanicals and manures could be effective strategies to sustain crop production as well as soil health. In organic farming**,** agricultural system uses ecologically based pest control and biological fertilizers derived largely from animal and plant wastes. Organic farming helps to sustain crop production and also maintains dynamic soil nutrient status and safe environment (Lokanath and

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Parameshwarappa, 2006). *Panchgavya* works as an efficient plant-growth stimulant that enhances the yield, side by side improves biological efficiency of the crop (Gore and Sreenivasa, 2011). *Panchgavya* contains lots of beneficial, effective microorganisms, namely lactobacillus bacteria, actinomycetes, yeast, photosynthetic bacteria and certain fungi besides beneficial and well-proven fertilizers such as *Acetobacter, Azospirillum* and *Phosphobacterium* which improve soil quality, growth and yield of crops (Xu and Xu, 2000; Selvaraj *et al*., 2007). Banana-pseudostem sap and seaweed extract increase nutrient uptake from the soil and maintain antioxidant properties, results in healthy growth and development of plants. Cow urine is a good source of nitrogen for plant growth and development. Application of FYM improves N, P and K content and further improves soil properties which makes soil fertile and healthy. A recent study confirmed that, application of inorganic fertilizer in soybean causes diversion of energy to the vegetative parts and leading to poor pod development and reduced yield (Behera, 2005).

To improve the sustained productivity in a cereal–legume cropping system, it is advised to use organics, which not only improve yield, soil properties but also reduce the cost of cultivation and maintain health and hygiene (Subbarao *et al*., 1998; Manna *et al.,* 2003). The improved yield in future would have to be harvested from vertical rather than horizontal expansion of net cropped area. Therefore, it is crucial to develop and adopt eco-farming techniques instead of inorganic fertilizers, which are ecologically sound, environmentally safe and economically efficient (Prajapat *et al.,* 2014). Hence an experiment was planned to test the productivity and profitability of soybean under various cow-based bio-enhancers and botanicals so that we can recommend the way of sustainability to the farmers, which will improve soil and human health as well as will reduce environmental pollution.

MATERIALS AND METHODS

A field experiment was conducted at Instructional Farm, Junagadh Agricultural University, Junagadh, (21.5° N, 70.5° E, 60 m above the mean sea-level), Gujarat, during 2018–19 and 2019–20. The site is enjoys a typically subtropical climate with fairly cold and dry winter and hot and dry summer. From June to September Junagadh receives total annual rainfall 1,072 mm. Average temperature was recorded 24.3°C and 22.6°C with relative humidity 58% and 51.5% during 2018–19 and 2019–20 respectively. The texture of the soil was clayey with medium organic carbon 0.69 and 0.66%, available phosphorus 24.45 kg/ha and 26.62 kg/ha, and available potassium 255 kg/ha and 252 kg/ha, while low in available nitrogen 225 kg/ha and 234 kg/ha during 2018–19 and 2019–20 respectively. The soil was neutral to slightly alkaline (*p*H 8.1 and 7.7 in 2018–19 and 2019–20). The experiment was laid out in a randomized block design with 12 treatments, which were replicated 3 times. The treatments consisted of control (T_1); 100% recommended dose of fertilizer (RDF): 30-60-0 NPK (T_2) (outside the organic plot); FYM @ 10 t/ha (T_3), FYM @ 5 t/ha + *Panchgavya* @ 3% as foliar spray at 30 and 60 days after sowing (DAS-T_4); FYM @ 5 t/ha + banana (*Musa* × *paradisciaca* L.) psedostem sap @ 1% as foliar spray at 30 and 60 DAS (T_5); FYM @ 5 t/ha + seaweed extract @ 3.5% as foliar spray at 30 and 60 DAS (T_6); FYM @ 5 t/ha + cow urine @ 3% as foliar spray at 30 and 60 DAS (T_7); vermicompost @ 4 t/ha (T_8); vermicompost @ 2 t/ha + *Panchgavya* @ 3% as foliar spray at 30 and 60 DAS (T_9); vermicompost @ 2 t/ha + banana pseudostem sap @ 1% as foliar spray at 30 and 60 DAS (T_{10}); vermicompost @ 2 t/ha + seaweed extract @ 3.5% as foliar spray at 30 and 60 DAS (T_{11}); and vermicompost @ 2 t/ha + cow urine @ 3% as foliar spray at 30 and 60 DAS (T_{12}). A seed rate of 60 kg/ha for soybean variety 'GJS 3' and 100 kg/ha, for wheat variety 'GW 366' was used. Soybean variety 'GJS 3' has determinate type growth, lodging resistance, non-shattering nature and contains better seed protein and oil content, while wheat variety 'GW 366' having resistance to leaf and stem rust disease under all conditions. Row-to-row spacing and plant-to-plant spacing were 45 cm × 10 cm and 22 cm × 10 cm used in soybean and wheat respectively. Fertilizer application was done as per the treatment in soybean, while there was no fertilizer application in wheat. During the experiment, use of herbicide was totally restricted and 2 hand-weedings were done manually to control the weeds in both the crops. Irrigation was given as per the requirement. Harvesting of the crop was done with the help of sickle by manually at the maturity when leaves turn yellow and pods became dry and left for sun-drying. Seven–eight days after harvesting, threshing was done to remove the straw from the pods and then winnowed.

Panchgavya was prepared at the Instructional farm by using nine ingredients (cow dung, cow urine, cow milk, cow milk curd, cow *ghee*, coconut water, banana, water and jaggery). The nutrient composition of various botanicals and bio-enhancers were analysed by standard procedures (Table 1). The data collected on different parameters were subjected to statistical analysis of variance (ANOVA) in a randomized complete-block design (RBD) with help of Online SSCNARS portal of the ICAR-Indian Agricultural Statistics Research Institute, New Delhi.

RESULT AND DISCUSSION

Yields attributes and yield of soybean

The pooled data of the 2 years showed significantly

Table 1. Nutrient compositions of botanicals and bio-enhancers

Particulars	N	P	K	Others
Panchgavya (ppm)	229	209	232	IAA, GA, Fungi, *Lactobacillus* etc.
Banana pseudostemsap (%)	–	0.5–0.7	5.6–6.2	Cytokinins, GA_3, Fe, Mn, Zn etc.
Seaweed extract (%)	0.3	0.1	1.0	Fe, Ca, Mn, Zn and Cu etc.
Cow urine (%)	2.5	–	–	Hormones, salt, minerals and enzymes
FYM (%)	0.5	0.2	0.5	Micronutrients, hormones, enzymes etc.
Vermicompost (%)	3.0	1.0	1.5	Micronutrients, hormones, enzymes etc.

highest number of pods/plant, seeds/pod, test weight, seed yield and stover yield of soybean were recorded with application of 100% RDF (T_2) over the control (T_1) (Table 2). However, among the organic treatments the highest yield attributes and yield of soybean were recorded with application of vermicompost @ 4 t/ha (T_8), followed by application of FYM @ 10 t/ha (T_3). Our results confirm the findings of Jat and Ahlawat (2004, 2006), Ghanshyam and Jat (2010), Mycin *et al.* (2010) and Khan *et al*. (2017). The soybean grain yield (2.46 t/ha) of T_8 treatment was 43.24% higher than the control (1.39 t/ha) and 1.86% lower to that of T_2 treatment. The highest harvest index (44.8%) was recorded with T_2, followed by T_8; however, it was found non-significant to other treatments. The application of various bio-enhancers and botanicals such as *Panchgavya* @ 3% as foliar spray at 30 and 60 DAS, banana pseudostem sap @ 1% as foliar spray at 30 and 60 DAS, seaweed extract @ 3.5% as foliar spray at 30 and 60 DAS and cow urine @ 3% as foliar spray at 30 and 60 DAS separately with FYM @ 5 t/ha and vermicompost @ 2 t/ha also influenced the yield attributes and yield of soybean. Among them, the highest grain yield of soybean was recorded with the application of vermicompost @ 2 t/ha + *Panchgavya* @ 3% as foliar spray at 30 and 60 DAS (T_9), followed by FYM @ 5 t/ha + *Panchgavya* @ 3% as foliar spray at 30 and 60 DAS (T_4). Chaudhari *et al.* (2013) also recorded the effect of *Panchgavya* in respect of yield and yield attributes.

Owing to high population of fungi, bacteria and actinomycetes microbial decomposition in vermicompost is high, that leads to better soil environment. It encourages proliferation of plant roots, which helped absorb more water and nutrients from larger soil area and deeper layers, and thus owing to higher availability of nutrients,

Table 2. Effect of botanicals and bio-enhancers on yield attributes and yields of soybean (pooled data of 2 years)

Treatment	Pods/ plant	Seeds/ pod	1000-grains (g)	Seed-yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
T_1, Control	30.67^{d}	2.87^{d}	12.22^{c}	1.40^{e}	1.91^{e}	42.2
T_2, 100% RDF: 30-60-0 NPK (outside the organic plot)	59.33^{a}	3.83^{a}	14.77^{a}	2.51^{a}	3.08^{a}	44.9
T_3, FYM @ 10 t/ha	58.50^{a}	3.70^{ab}	14.33^{ab}	2.37^{abc}	3.0^{abc}	44.1
T_4, FYM @ 5 t/ha + *Panchgavya* @ 3% as foliar spray at 30 and 60 DAS	56.67^{ab}	3.55^{abc}	14.18^{ab}	2.32^{abcd}	2.93^{abcd}	43.9
T_5, FYM @ 5 t/ha + banana pseudostem sap @ 1% as foliar spray at 30 and 60 DAS	47.17^{bc}	3.17^{bcd}	13.38^{bc}	1.94^{cd}	2.64^{bcd}	42.1
T_6, FYM @ 5 t/ha + seaweed extract @ 3.5% as foliar spray at 30 and 60 DAS	45.83^{c}	3.03^{cd}	13.20^{bc}	1.85^{de}	2.56^{d}	41.8
T_7, FYM @ 5 t/ha + cow urine @ 3% as foliar spray at 30 and 60 DAS	49.33^{abc}	3.32^{abcd}	13.70^{ab}	2.06^{abcd}	2.72^{abcd}	42.9
T_8, Vermicompost @ 4 t/ha	58.67^{a}	3.73^{ab}	14.72^{a}	2.46^{ab}	3.04^{ab}	44.7
T_9, Vermicompost @ 2 t/ha + *Panchgavya* @ 3% as foliar spray at 30 and 60 DAS	57.67^{a}	3.58^{abc}	14.18^{ab}	2.33^{abcd}	2.96^{abcd}	43.9
T_{10}, Vermicompost @ 2 t/ha + banana pseudostem sap @ 1% as foliar spray at 30 and 60 DAS	49.17^{abc}	3.25^{abcd}	13.63^{ab}	2.01^{bcd}	2.68^{abcd}	42.7
T_{11}, Vermicompost @ 2 t/ha + seaweed extract @ 3.5% as foliar spray at 30 and 60 DAS	46.33^{c}	3.15^{bcd}	13.35^{bc}	1.90^{cd}	2.61^{cd}	42.0
T_{12}, Vermicompost @ 2 t/ha + cow urine @ 3% as foliar spray at 30 and 60 DAS	50.00^{abc}	3.30^{abcd}	13.63^{ab}	2.07^{abcd}	2.72^{abcd}	43.1
SE(d)	2.98	0.17	0.34	0.14	0.12	1.1
Tukey's HSD at 5%	10.29	0.58	1.17	0.50	0.41	NS

DAS, Days after sowing

synthesis of more carbohydrates and their translocation to different plant parts. Vermicompost is a well-known nutrient reservoir, and after decomposition it provides food for growth of bacteria, results in higher dry-matter accumulation. The improvement of crop growth results enhanced seed and stover yields of soybean.

Yield attributes and yields of wheat under residual soil fertility

Number of spikelets/spike, grains/spike, 1,000-grain volume, 1,000-grain weight, grain yield and straw yield significantly affected by the residual effect of the different treatments (Table 3). Significantly higher number of spikelets/spike, grains/spike, 1,000-grains volume, 1,000-grain weight, grain yield and straw yield in wheat crop was recorded under treatment vermicompost @ 4 t/ha over the other treatments. Further, the treatment FYM @ 10 t/ha resulted in significantly higher number spikelets/spike, grains/spike 1,000-grain volume, 1,000-grain weight, grain yield and straw yield of wheat crop over rest of the treatments, indicating that all the organic substances sustained in the soil as a residue. The sustainability of vermicompost as a residue in soil and its effect in form of yield was also reported by Machhar and Patel (2015) and Kumar *et al.* (2017). However, effect of inorganic treatment was up to the mark on the wheat crop as these were easily taken by the soybean crop. Application of vermicompost @ 4 t/ha to soybean resulted in an increment of wheat grain yield (3.90 t/ha) and straw yield (6.95 t/ha), being 33.14% in grain and 32.44% in straw over the 100% RDF.

Cultivation of wheat after rainy (*kharif*) season crop saves fertilizer dose, because soybean balance the nutrients by creating favourable environment in the rhizosphere of wheat crop like-improve the soil porosity, water-holding capacity and nutrient-use efficiency of the wheat crop which leads to uptake more nutrient and moisture (Ramesh *et al.,* 2008). Application of vermicompost provides favourable physical environment that helps in nutrient transformation and absorption from the soil and helps in vegetative growth as well as reproductive phase of plants. Since the added organic sources did not mineralize completely within the season of application, some amount is left undecomposed or un-mineralized and this portion benefit the succeeding crop through the supplementation of plant nutrients and improvement in soil physical environment.

Economics

On the basis of pooled data of 2 years (Table 4) it was observed that, significantly higher gross realizations and cost of cultivation in soybean were recorded under treatment vermicompost @ 4 t/ha over the other treatments, i.e. 148,205.08/ha. The treatment FYM @ 5 t/ha + *Panchgavya* @ 3% as foliar spray at 30 and 60 DAS also

Table 3. Residual effect of different botanicals and bio-enhancers on yield attributes and yields of wheat (pooled data of 2 years).

Treatment	Spikelets/ spike	Grains/ spikes	1,000-grain volume (ml)	1,000-grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)
T_1, Control	8.83^{e}	23.50^{e}	30.83^{c}	35.00^{c}	2.361^{f}	3.324^{f}
T_2, 100% RDF: 30-60-0 NPK (outside the organic plot)	9.83^{de}	28.00^{de}	35.50^{bc}	43.67^{b}	2.934^{ef}	5.250^{e}
T_3, FYM @ 10 t/ha	12.83^{ab}	33.67^{ab}	41.83^{ab}	51.00^{ab}	3.787^{ab}	6.861^{a}
T_4, FYM @ 5 t/ha + *Panchgavya* @ 3% as foliar spray at 30 and 60 DAS	11.17^{abcd}	29.67^{abcd}	36.83^{abc}	44.83^{ab}	3.259^{bcde}	5.602^{bcde}
T_5, FYM @ 5 t/ha + banana pseudostem sap @ 1% as foliar spray at 30 and 60 DAS	10.33^{cde}	28.50^{cd}	36.83^{abc}	44.00^{b}	3.102^{cde}	5.379^{de}
T_6, FYM @ 5 t/ha + seaweed extract @ 3.5% as foliar spray at 30 and 60 DAS	10.00^{de}	28.33^{cd}	35.83^{bc}	44.17^{ab}	3.009^{de}	5.324^{de}
T_7, FYM @ 5 t/ha + cow urine @ 3% as foliar spray at 30 and 60 DAS	10.67^{bcde}	29.17^{bcd}	36.83^{abc}	44.50^{ab}	3.203^{bcde}	5.564^{cde}
T_8, Vermicompost @ 4 t/ha	13.17^{a}	34.33^{a}	42.83^{a}	51.83^{a}	3.907^{a}	6.953^{a}
T_9, Vermicompost @ 2 t/ha + *Panchgavya* @ 3% as foliar spray at 30 and 60 DAS	12.50^{abc}	33.50^{ab}	41.17^{ab}	50.50^{ab}	3.685^{abc}	6.787^{ab}
T_{10}, Vermicompost @ 2 t/ha + banana pseudostem sap @ 1% as foliar spray at 30 and 60 DAS	11.67^{abcd}	32.17^{abcd}	40.17^{ab}	48.50^{ab}	3.490^{abcde}	6.527^{abcd}
T_{11}, Vermicompost @ 2 t/ha + seaweed extract @ 3.5% as foliar spray at 30 and 60 DAS	11.67^{abcd}	32.17^{abcd}	39.50^{ab}	48.17^{ab}	3.426^{abcde}	6.416^{abcde}
T_{12}, Vermicompost @ 2 t/ha + cow urine @ 3% as foliar spray at 30 and 60 DAS	12.33^{abc}	33.00^{abc}	40.83^{ab}	49.50^{ab}	3.573^{abcd}	6.638^{abc}
SE(d)	0.632	1.357	1.989	2.227	0.179	0.352
Tukey's HSD at 5%	2.1786	4.6819	6.8614	7.6805	0.619	0.1215

DAS, Days after sowing

showed higher net returns (129,694.34/ha) and benefit: cost (B: C) ration (4.53), followed by treatment T_3 (FYM @ 5 t/ha) over the other organic and inorganic treatments. The cost of *Panchgavya* and FYM when applied in combination was low as compared to the inorganic and vermicompost. Our results confirm the findings of Yadav and Christopher (2006). Farmyard manure contains lots of beneficial nutrients and *Panchagavya* is also rich in macro and micronutrients with beneficial growth hormones, so it gave optimum yield and got premium price with very low input cost with respect of other treatments.

It can be concluded that, higher production and net returns from soybean under organic cultivation could be secured by the application of FYM @ 5 t/ha + *Panchgavya* as foliar spray @ 3% at 30 and 60 DAS, which also improves soil fertility and biological properties of soil. For higher productivity and sustainability of wheat–soybean cropping system, adoption of organic farming is a boon. The promotion of organic farming instead of inorganic fertilizer leads to enhance the production of crop without alerting the environment all over the world.

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Table 4. Effect of different botanicals and bio-enhancers on economics of soybean (pooled data of 2 years)

Treatment	Gross realization (₹/ha)	Cost of cultivation (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
T_1, Control	100,780^{e}	29,243^{l}	71,537^{d}	3.44^{bc}
T_2, 100% RDF: 30-60-0 NPK (outside the organic plot)	133,212^{de}	33,911^{k}	99,301^{abcd}	4.01^{ab}
T_3, FYM @ 10 t/ha	169,883^{ab}	41,572^{f}	128,311^{a}	4.09^{ab}
T_4, FYM @ 5 t/ha + *Panchgavya* @ 3% as foliar spray at 30 and 60 DAS	166,439^{abc}	36,745^{i}	129,694^{a}	4.53^{a}
T_5, FYM @ 5 t/ha + banana pseudostem sap @ 1% as foliar spray at 30 and 60 DAS	139,22^{bcd}	37,426^{h}	101,802^{abcd}	3.72^{abc}
T_6, FYM @ 5 t/ha + seaweed extract @ 3.5% as foliar spray at 30 and 60 DAS	133,231^{de}	39,172^{g}	94,058^{bcd}	3.40^{bc}
T_7, FYM @ 5 t/ha + cow urine @ 3% as foliar spray at 30 and 60 DAS	148,205^{abcd}	36,064^{j}	112,142^{abc}	4.11^{ab}
T_8, Vermicompost @ 4 t/ha	176,026^{a}	52,930^{a}	123,096^{abc}	3.32^{bc}
T_9, Vermicompost @ 2 t/ha + *Panchgavya* @ 3% as foliar spray at 30 and 60 DAS	167,388^{abc}	42,424^{d}	124,964^{ab}	3.95^{ab}
T_{10}, Vermicompost @ 2 t/ha + banana pseudostem sap @ 1% as foliar spray at 30 and 60 DAS	144,479^{abcd}	43,105^{c}	101,374^{abcd}	3.35^{bc}
T_{11}, Vermicompost @ 2 t/ha + seaweed extract @ 3.5% as foliar spray at 30 and 60 DAS	136,527^{cd}	44,851^{b}	91,676^{cd}	3.04^{c}
T_{12}, Vermicompost @ 2 t/ha + cow urine @ 3% as foliar spray at 30 and 60 DAS	148,898^{abcd}	41,742^{e}	107156^{abc}	3.57^{bc}
SE(d)	8,969	0	8,969	0.23
Tukey's HSD at 5%	32,625	0	32,625	0.8358

DAS, Days after sowing

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