Research Article

Soil Application of *Trichoderma* and Peach (*Prunus persica* L.) Residues Possesses Biocontrol Potential for Weeds and Enhances Growth and Profitability of Soybean (Glycine max)

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Abstract | Weed is a limiting factor to various economically important agricultural crops including cereal, oil seed, legumes and cash crops. Minimizing pest losses in addition to better crop management is a way toward narrowing the yield gap and ensuring food security. The present study was carried out to investigate the impact of peach (*Prunus persica* L.) residues and soil application of *Trichoderma* (soft-rot fungi) along with seed inoculation of phosphate solubilizing bacteria (PSB) (*Pseudomonas*) and phosphorus (P) on weeds frequency, and biomass at various growth stages of soybean and its yield contributing parameters. The consecutive field experiments for years 2016 and 2017 using randomized complete block design (RCBD) were conducted on soybean (cv. Malakand-96) crop. Experimental treatments included three organic sources, three phosphate rates and two beneficial microbes. Weeds found during the whole growing period of soybean crop were *Euphorbia heterophylla* L, *Phyllanthus fraternus* L., *Portulaca oleracea* L., *Parthenium hysterophorus* L., *IPomoea nil* L., *Erigeron canadensis* L., *Echinochloa crus-galli* L., *Asparagus officinalis* L., *Cynodon dactylon* L., *Digera muricata* L., *Cyprus rotundus* L. *and Solanum nigrum* L. The most abundant and flourished weeds were *Cyprus rotundus* L, and *Cynodon dactylon*. Results revealed that peach organic sources (biochar) and *Trichoderma* drastically reduced weeds frequency, weeds biomass at flowering, pods formation and physiological maturity stages. However, P highest and moderate (100 and 75 kg P ha^{-1}) rates were remained the same for weeds biomass. When compared with the economic analysis and profitability of soybean the highest net returns (NR) in Pakistani Rupees (PKRs) (PKR 62.082 ha^{-1}) were noted with the biochar amendment followed by compost (PKR 60,168 ha^{-1}), whereas least net return NR (PKR 41,548 ha^{-1}) was recorded with peach residues incorporation. The value cost ratio (VCR) was highest with compost application (5.48) among the organic sources followed by biochar (5.37), while the least VCR value (4.67) was observed with peach residues. Beneficial microbe's application indicated that highest NR (PKR 67,453 ha^{-1}) were attained with soil application of *Trichoderma* followed by seed inoculation of PSB (PKR 62,695 ha^{-1}). When compared the average VCR of both years, greater VCR was attained by *Trichoderma* followed by PSB.

Received | January 03, 2019; **Accepted** | December 1, 2019; **Published** | January 10, 2020
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Citation | Imran, Amanullah, M. Arif, Z. Shah and A. Bari. 2020. Soil application of *Trichoderma* and peach (*Prunus persica* L.) residues possesses biocontrol potential for weeds and enhances growth and profitability of soybean (Glycine max). *Sarhad Journal of Agriculture,* 36(1): 10-20.
DOI | http://dx.doi.org/10.17582/journal.sja/2020/36.1.10.20
Keywords | Beneficial microbes (PSB and *Trichoderma*), Biochar, Compost, Peach residues, Profitability, Weeds, Biomass, Growth, Soybean

Introduction

Several factors affect growth and yield of agronomic crops. The most important factor responsible for reduction in yield is weeds competition with crop for available resources (Imran et al., 2016). Poor yields of cereals has been associated with lack of proper resources and weed management (Harman et al., 2004; Druzhinina et al., 2006; Ali et al., 2018). Weed threats occur at various crop growth stages (Atehnkeng et al., 2008; Gilardi et al., 2008; Mukherjee et al., 2012; Imran, 2018). In addition to the availability of essential nutrients and soil moisture, successful cereals cultivation largely depends on efficient weed control (Hjeljord et al., 2000). In addition to competing for water and nutrients weeds also serve as alternative host to various pathogens or their insect carriers (Imran et al., 2017). Utilizing the fertilizers and water use to the bursting potential is dependent effective weeds control strategies (Steyaert et al., 2003), and necessitates the proper eradication measures for enhancement of soil health (Howell, 2003; Yaqub and Shahzad, 2008; Vinale et al., 2008). Severe loses up to 70 % in yield of soybean has been reported by many researchers (Howell et al., 2000; Yedidia et al., 2003; Harman et al., 2004). For effective weeds control, most farmers use herbicide, which degrades the soil environment as well as the atmospheric environment and human health (Herrera-Estrella and Chet, 2004; Har-man, 2006; Vinaleet al., 2008; Imran et al., 2016). *Trichoderma* spp. are highly successful colonizers of their habitats, which is reflected both by their efficient utilization of the substrate at hand as well as their secretion capacity for antibiotic metabolites and enzymes (Schaster and chmoll, 2010). *Trichoderma* are successful in biological control because they have shown variously an ability to parasitize pathogenic fungi, and produce compounds that are toxic to weeds, or enzymes that lyse the cell walls of non-hosted plants (Atehnkeng et al., 2008). They may also enhance plant growth and vigor, enabling the host plant to successfully defend itself against attack. This study was conducted to evaluate the impact of soil application of *Trichoderma* along with P and peach residues for biocontrol of weeds and to enhance soil health and profitability of the farmers with the advantage to indicate the direction for future research on studies related to biocontrol potential of Trichoderma under field condition.

Materials and Methods

Field experiments were conducted for two consecutive years at Agriculture Research Institute Mingora (ARI) Swat, Pakistan in summer seasons of 2016 (year 1) and 2017 (year 2) on soybean (cv. Malakand-96) crop. The experiments were carried out in a randomized complete block design (RCBD) with three replications. Experimental treatments were comprised on organic sources @ 1 kg m^{-2}(peach residues, leaves and fruits *having no stones (partially decomposed), its well decomposed compost* comprised of leaves and fruits having no stones and its biochar (peach tree stem, with peach stones, leaves and twigs), three phosphorus levels and two beneficial microbes, PSB (*Pseudomonas,* (bacteria) and *Trichoderma* (soft-rot fungi). The required P levels, using single superphosphate (SSP) as source of P and beneficial microbes (*Trichoderma* and PSB) were applied along with basal dose of N (urea) (25 kg ha^{-1}) at the time of sowing. The field was ploughed twice up to the depth of 30 cm with the help of cultivator followed by planking. The plot size kept was 4 m in length and 2.7 m in width (10.8 m^2) with row to row spacing of 45 cm and plant to plant distance of 5 cm. Soybean (*cv.* Malakand-96) was sown at the rate of 100 kg ha^{-1} on July 4^{th} 2016 and 2017, respectively. PSB was inoculated to soybean seed (20 g kg^{-1} seed) for the required treatment at the time of sowing, whereas *Trichoderma* was incorporated (@ 2000 g ha^{-1}) in to the soil in each plot at the time of sowing. PSB and *Trichoderma* were provided by Agriculture Research Institute Mingora Swat for this study. Climatic data and physico-chemical properties of soil before planting soybean for both the years are presented in Figure 1 and Table 1. The data was analyzed according to Steel et al. (1996) and mean of both years were compared using LSD test ($P \leq 0.05$).

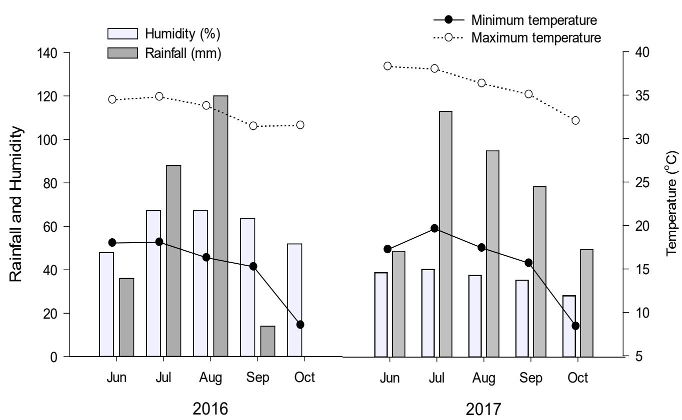

Figure 1: *Rain fall, humidity and temperature (Max, Min) for the year 2016 and 2017.*

Table 1: *Soil analysis of the experimental site for both years (2016 and 2017).*

Soil property	Unit	Year 2016	Year 2017
Clay	%	11.6	11.6
Silt	%	50	50
Sand	%	38.4	38.4
Textural Class	-	Silt loam	Silt loam
pH (1:5)	-	5.8	6
Organic Matter	%	1.38	4.18
Lime contents	%	4	2
Total Nitrogen	%	0.069	0.16
AB-DTPA extract. P (ppm)	mg kg^{-1}	10.28947	14.26
AB-DTPA extract. K (ppm)	mg kg^{-1}	76	186

Experimental detail and soil texture

Experiment was carried out at ARI Swat and located at the temperate region of KP, Pakistan. Average rainfall at Swat varies from 750 to 900 mm $annum^{-1}$. Experimental field soil was silt loam in nature with acidic characteristic deficient in soils organic matter, N, P and available K (Table 1).

Methodology for data collection and economic analysis

Data was collected on emergence m^{-2}, days taken to emergence, branches produced $plant^{-1}$, leaves $plant^{-1}$, weeds frequency and weeds biomass at three stages (flowering, pods and physiological maturity). Emergence m^{-2} was noted with the help of quadrates thrown randomly in each plot, counted the emerged plants and then averaged. Days to emergence was carried out on visual based observation and counted from date of sowing till emergence. Branches and leaves $plant^{-1}$ were counted randomly in five selected plants and then averaged. Weeds frequency was noted with the help of quadrates thrown in each plot and then weeds were identified according to the genera and specie, counted and then averaged each genera and specie of weeds. Weeds biomass at each stage (flowering, pods and physiological maturity) was calculated in each plot over the both years. Weeds were uprooted at each stage and fresh and dry weight was determined with the help of electronic balance. Economic analysis was carried out on the basis of phosphorus, beneficial microbes and organic sources application (Table 4). Economic analysis was based on current market price of soybean grain kg^{-1}, soybean straw price kg^{-1}, peach residues cost for collection, transportation, compost making, biochar preparation and labor cost was included. Similarly, retail price of P and beneficial microbes was kept according to current market rate of each year. Retail price (RP) of 1 kg soybean grain in PKRs = 56.00; Soybean straw RP kg^{-1} = 04.00; Residues cost in PKRs = 8,250 and 9,510; Compost cost in PKRs = 10,440 and 11,490; Biochar cost in PKRs = 10,800 and 12,300 was in each year of study (2016 and 2017); Price for 1 kg phosphorous in PKRs = 105; Price of Trichoderma for 1 hectare in PKRs = 4,700; Price of PSB for 1 hectare in PKRs = 5,280; * Value cost ratios determined using net returns values.

Table 2: *Days to emergence (DE), emergence m^{-2} (Em^{-2}), number of branches $plant^{-1}$ (NBP) and number of leaves $plant^{-1}$ (NLP) of soybean as influenced by organic sources, beneficial microbes and phosphorus levels (data pooled for the two year of 2016 and 2017).*

Treatments	DE	Em^{-2}	NBP	NLP
Organic Sources (OS)				
Peach Residues	10.6	21.6	15.8c	124b
Peach Compost	10.8	22.4	18.8a	133a
Peach Biochar	11.3	21.7	16.7b	132a
LSD $_{0.05}$	ns	ns	0.6	2.96
Beneficial Microbes (BM)				
PSB	10.9	22.2	16.6b	127b
Trichoderma	10.9	21.7	17.6a	129a
Sig Level	ns	ns	***	***
Phosphorus (kg ha^{-1})				
50	10.8	21.9	14.8b	121c
75	11.0	20.3	18.4a	131b
100	10.9	21.9	18.1a	136a
LSD $_{0.05}$	ns	ns	0.59	2.96
Years (Y)				
2016	10.9	19.9	17.3	128.3
2017	10.9	22.0	16.9	130.4
Sig Level	ns	ns	ns	Ns
Planned Mean Comparison				
Control	10.8	22.0	14b	118b
Rest	10.9	21.9	17a	129a
Sig Level	ns	ns	***	***

*Whereas *** = $p < 0.001$, ** = $p < 0.01$ and * = $p < 0.05$ though ns, stand for non-significant.*

Results and Discussion

Phenological and growth parameters of soybean

Days to emergence: Organic sources, beneficial microbes and phosphorus levels and its interactions (OS x BM x PL) had non-significant effect on days to emergence (Table 2). The assessment regarding emergence was same in all treated plots as compared to control. It could be concluded that emergence capability might be genetic character of the cultivar (Gilardi et al., 2008; Mukherjee et al., 2012; Imran, 2018; Howell, 2003). The findings are supported by Muhammad et al. (2016) and Paliwal et al. (2011) who reported that emergence did not respond positively to biochar and other organic amendments. Similar results were reported by Waghmare et al. (2014), who reported that germination behaviour and vigour of seed under various treatments was not significantly different compared with non-treated plots. Although Callan et al. (1991) reported that emergence increased with the inoculation of beneficial microbes. Similarly, Thakur et al. (2011) and Ahmad et al. (2014) revealed that interaction of genotype and environment can affect the final establishment of the seedling.

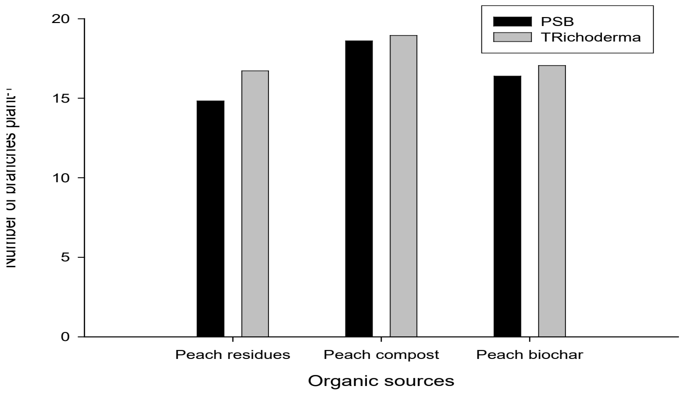

Figure 2: *Interaction between organic sources and beneficial microbes for number of branches plant^{-1}.*

Emergence (m^{-2}): Peach residues, compost and biochar (OS), phosphorus levels and beneficial microbes had non-significant effect on emergence m^{-2} (Table 2). The reason could be that all these treatments have no capability to bring chemical changes in the seed and activate enzymes to lead the seed for quick emergence (Yedidia et al., 2003; Harman et al., 2004; Herrera-Estrella and Chet, 2004). These findings are in relation with Muhammad et al. (2016) and Ali et al. (2018) who concluded that biochar and its various rates did not enhance seed viability, seeds germination behaviour and other traits of soybean seeds. The results are in line with those of Aise et al. (2011) who reported that P application did not affect emergence m^{-2} of soybean. Ahmad et al. (2013) reported that chemical and bio fertilization did not affect emergence m^{-2} of soybean crop. Our results were in contrast with those of Alahdadi et al. (2009) who discovered that soybean emergence index and germination percentage increased with P application. Imran and Amanullah (2018) reported that biochar, P and beneficial microbes enhance soil health and soybean productivity. The justification of our results could be that, at the time of emergence, the seeds lacks of real and permanent roots to uptake P and other nutrients that's why our results in contrast with the above findings.

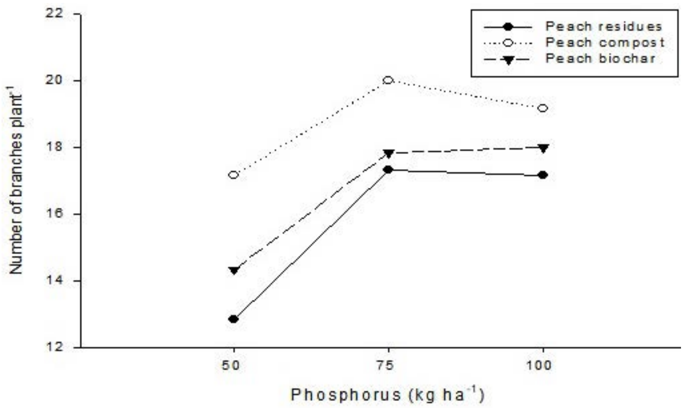

Figure 3: *Interaction between organic sources and phosphorus level for number of branches plant^{-1}.*

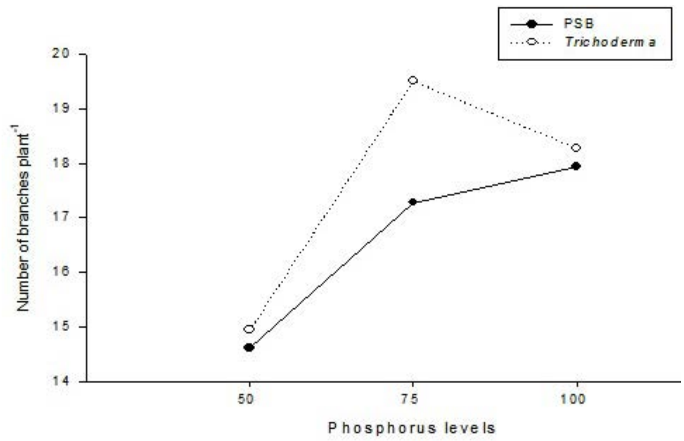

Figure 4: *Interaction between phosphorus level and beneficial microbes for number of branches plant^{-1}.*

Number of branches plant^{-1}: Perusal of the data showed that branches plant^{-1} was significantly enhanced with organic sources, phosphorus and beneficial microbes (Table 2). Maximum branches plant^{-1} (17) were noted in rest plots as compared to control plots. Peach compost showed maximum value for branches plant^{-1} (19) followed by biochar (17) amendments, whereas peach residues produced minimum branches plant^{-1} (16). Beneficial microbes also showed ameliorating effect on number of branches plant^{-1} and *Trichoderma* treated plots gave more branches than seed inoculation of PSB (17). In case of P treatments, significantly higher values of branches per plant (18.4) was recorded by application of 75 kg P ha^{-1} being at par with 100 kg P ha^{-1} (18.1), whereas lowest branches (14.8) plant^{-1}were recorded with 50 kg P ha-1. The interactions between OS x BM, OS x PL, BM x PL and OS x BM x PL were found significant (Figures 2, 3, 4 and 5). Alahdadi et al. (2009) reported that soil amendments increased significant shoot length and biomass plant-1 (Vinale et al., 2008; Imran et al., 2016; Komon-Zelazowska et al., 2007). Chakraborty et al. (2016) supported the above statements and concluded that soybean growth and yield was better with incorporation of compost than FYM. It could be attributed to comparatively better regulated supply of nutrients by the compost as compared to biochar and peach dry based residues. These results are also in corroboration with Akter et al. (2013) and Ali et al. (2018) who reported that soybean plant growth, plant biomass and branches plant-1 improved with incorporation of organic amendments (Imran et al., 2016; Harman et al., 2004).

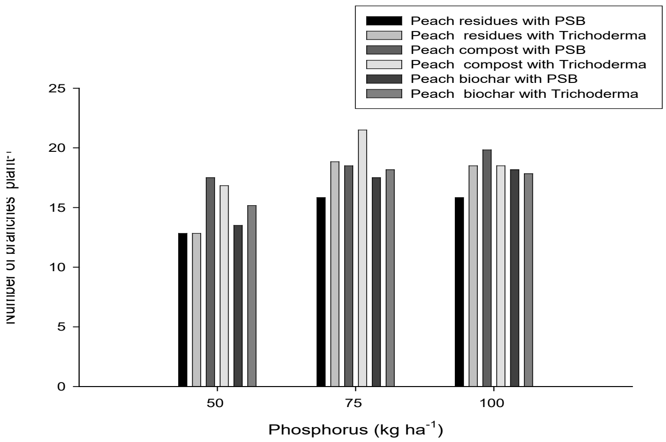

Figure 5: *Interaction among organic sources, phosphorus level and beneficial microbes for number of branches plant-1.*

Number of leaves plant-1: Organic sources, phosphorus levels, beneficial microbes and control vs rest plots ensured highest leaves plant-1 while year effect was non-significant (Table 2). The rest plots had maximum leaves plant-1(129) as compared to control plot (118). Among the organic sources, compost and biochar amendments produced on par value leaves plant-1 (133 and 132) followed by peach residues (124). This might be due to the capability of essential nutrients supply for vigorous and flourished growth that might have brought morphological changes in the plant canopy and enhanced leaf numbers respectively (Ali et al., 2015; Arif et al., 2017; Steyaert et al., 2003; Howell et al., 2000). Bbeneficial microbes' application enhanced number of leaves and soil application of *Trichoderma* produced more leaves plant-1 (129) as compared to PSB (127). Phosphorous application enhanced leaves in soybean from lowest to the highest level (50 to 100 kg ha-1). Maximum leaves plant-1 (136) were produced by plots treated with 100 kg P ha-1 followed by P treated with 75 kg ha-1 (131) whereas lowest leaves plant-1 (121) was recorded with 50 kg P ha-1. The possible reasons could be that beneficial microbes solubilize soil P and enhance P supply and ultimately crop productivity (Harman et al., 2004; Druzhinina et al., 2006; Ali et al., 2018). Akhtar et al. (2009), Akpalu et al. (2014) stated that higher crop yield was resulted from availability and solubilisation of fixed soil P by the beneficial microbes' application. Beneficial microorganisms having phosphate solubilizing potential may increase the availability of phosphate and improving biological nitrogen fixation in legumes and soybean crop (Herrera-Estrella and Chet, 2004; Harman 2006; Vinale et al., 2008). Interaction between OS x BM increased leaves quantity when compost and *Trichoderma* was combine applied. Interaction between OS x PL showed that more leaves plant-1produced with compost and 100 kg P ha-1. Interaction between BM x PL revealed that leaves quantity was increased with *Trichoderma* along with 100 kg P ha-1.

Biocontrol of weeds

Weeds frequency (m-2): Weeds frequency was substantially diverse in control plot as compared to rest plots (Table 3). Organic sources and years significantly affected weeds frequency. More generous of weeds were noted in peach residues and compost, followed by biochar application correspondingly. Temporal effect was significant and noted that in year 1 weeds frequency (6) was greater than year 2. The most flourished and abundant weeds were "*Cynodon dactylon* L". and "*Cyprus rotundus* L". The interaction between Y x OS had maximum weed frequency with application of peach residues in year 1. The reason for low weeds frequency might be *Trichoderma* contributes biocontrol potential and act as an herbicide by secretion of secondary metabolites (Herrera-Estrella and Chet, 2004; Harman 2006; Vinale et al., 2008; Howell, 2003; Yaqub and Shahzad, 2008; Vinale et al., 2008). The results were supported by Ali et al. (2015) who illustrated herbicidal potential of four *Trichoderma* species viz. "T. harzianum Rifai, T. pseudokoningii Rifai, T. reesei Simmons and T. viride Pers. against Rumexdentatus", an important and noxious weed of wheat by foliar application (Herrera-Estrella and Chet, 2004; Harman 2006; Vinaleet al., 2008).

Weeds biomass at flowering stage (g m-2): Control plots had maximum weeds biomass (146.4 g m-2) as compared to rest plots (76.3 g m^{-2}) (Table 3). Organic sources significantly reduced weeds biomass by the application of peach compost. Peach residues produced more biomass (88.5 g m^{-2}) as compared to biochar amendments (81.2 g m^{-2}). In case of beneficial microbes, soil application of *Trichoderma* was promising in weeds biomass reduction as compared to PSB (84.9 g m^{-2}). The findings were supported by Imran et al. (2016) who reported that *Trichoderma* have chemically divers secondary metabolites having plant inhibitor potential which may reduce weeds growth and biomass. These findings were found in connection with those of Herrera-Estrella and Chet (2004), Har-man (2006) and Vinale et al., (2008) who reported that beneficial microbe's application to soil act as a biocontrol agent for pathogens and weeds.

Table 3: *Weeds frequency (m^{-2}) WF, weeds biomass at flowering stage (WBFS) (g m^{-2}), weeds biomass at pods formation stage WBPS (g m^{-2}) and weeds biomass at physiological maturity stage WBPMS (g m^{-2}) of soybean as influenced by organic sources, beneficial microbes and phosphorus levels (data pooled for the two year of 2016 and 2017).*

Treatments	WF	WBFS	WBPS	WBPMS
Organic Sources (OS)				
Peach Residues	7a	88.5a	86.5a	63.5a
Peach Compost	7a	59.2b	60.6b	55.3b
Peach Biochar	6b	81.2a	83.5a	48.2c
LSD $_{0.05}$	1.0	10.71	10.17	5.66
Beneficial Microbes (BM)				
PSB	7	84.9a	82.9a	59.5a
Trichoderma	5	67.8b	70.9b	51.8b
Sig Level	**	***	**	**
Phosphorus (kg ha^{-1})				
50	7	60.6b	59.9b	40.7b
75	6	82.9a	84.4a	61.8a
100	6	85.5a	86.3a	64.5a
LSD $_{0.05}$	ns	10.71	10.17	5.66
Years (Y)				
2016	8a	75.0	85.3	51.6
2017	5b	77.6	68.4	59.7
Sig Level	*	Ns	Ns	Ns
Planned Mean Comparison				
Control	12a	146.4a	144.0a	66.8a
Rest	6b	76.3b	76.9b	55.7b
Sig Level	***	***	***	*

*Whereas *** = $p < 0.001$, ** = $p < 0.01$ and * = $p < 0.05$ though ns, stand for non-significant.*

Phosphorus levels had significant effect on weeds biomass and highest weeds biomass (85.5 g m^{-2}) was recorded with 100 kg P ha^{-1}, followed by 75 kg P ha^{-1}. Minimum weeds biomass (60.6 g m^{-2}) was noted with 50 kg P ha^{-1} application. The possible reason for higher weeds biomass at highest P level along with PSB application depends on frequent supply of P (Herrera-Estrella and Chet, 2004; Har-man, 2006; Vinale et al., 2008; Imran et al., 2016).

Interaction between OS x BM, OS x PL, BM x PL and OS x BM x PL was significant and observed that maximum weeds biomass was noted as P level were increased from 50 to 100 kg ha^{-1} along with the application of biochar and dry based peach residues. Interaction between OS x BM x PL showed that maximum weeds biomass produced with application of peach residues and biochar, PSB along with P application at the rate of 100 kg ha^{-1}. Vinale et al., (2008) and Imran et al. (2017) stated that Trichoderma is a very effective biological mean for plant disease management especially the soil born. It is a free-living fungus and common in soil and root ecosystems. It is highly interactive in root, soil and foliar environments. It reduces growth, survival or infections caused by pathogens by different mechanisms like competition, antibiosis, mycoparasitism, hyphal interactions, and enzyme secretion. They further stated that biological potential of Trichoderma for weeds control has been realized in recent years known as mycoherbicides application.

Weeds biomass at pods development stage (g m^{-2}): Control plots produced highest weeds biomass (144.0 g m^{-2}) as compared to rest plots (76.9 g m^{-2}) (Table 3). At this stage of the plant promising reduction in weeds biomass was noted with Trichoderma (70.9 g m^{-2}) than PSB (82.9 g m^{-2}). This could be attributed to biocontrol of weeds by using Trichoderma known as fungal pathogen. Phosphorus levels had also significant effect on weeds biomass and highest weeds biomass (86.3 g m^{-2}) were recorded with 100 kg P ha^{-1}, followed by at par 75 kg P ha^{-1}. Minimum weeds biomass was noted with 50 kg P ha^{-1} (59.9 g m^{-2}). The interaction between OS x BM x PL was significant and noted that weeds biomass was increased with application of peach residues and PSB along with P application at 100 kg P ha^{-1}. Akpalu et al. (2014) reveal that diverse chemical secretion of *Trichoderma* spp. may reduce and supress weeds growth working as a biocontrol agent (Komon-Zelazowska et al., 2007;

Imran et al., 2016, 2017). Trichoderma is a potent biocontrol agent and used extensively for weeds control and soil borne diseases. It has been used successfully against pathogenic fungi belonging to various genera, viz. Fusarium, Phytopthara, Scelerotia etc.

Weeds biomass at physiological maturity stage (g m^{-2}): Control plots produced absolute weeds biomass (66.8 g m^{-2}) as compared to rest plots (55.7 g m^{-2}) (Table 3). Organic sources application had significant effect on weeds biomass at maturity stage. Reduction in weeds biomass at this stage was maximum with application of peach biochar (48.2 g m^{-2}) followed by peach compost (55.3 g m^{-2}). Dry based peach residues amendments produced maximum weeds biomass (63.5 g m^{-2}). In case of beneficial microbe's application, drastic reduction in weeds biomass was noted with Trichoderma (51.8 g m^{-2}) as compared to PSB (59.5 g m^{-2}). The possible reason might be due to several Trichoderma increase root branching and increase shoot biomass as a consequence of cell division, expansion and differentiation by the presence of fungal auxin like compound which dominate the plant canopy and suppress weeds growth and development.

Phosphorus levels had also significant effect on weeds biomass and highest weeds biomass (64.5 g m^{-2}) were recorded where P was treated at the rate of 100 kg ha^{-1}, followed by at par 75 kg P ha^{-1}.

Minimum weeds biomass was noted with 50 kg P ha^{-1} application (40.7 g m^{-2}). Interaction between OS x PL, BM x PL and OS x BM x PL was significant and observed that maximum weeds biomass was noted as P levels were increased from 50 to 100 kg ha^{-1} along with application of biochar (Figure 7). Interaction between OS x BM x PL (Figure 6) showed that weeds biomass increased with application of peach residues, PSB along with 100 kg P ha^{-1}. Imran et al. (2016) reported that crop residues amendments may enhance weeds density and weeds biomass. Akhtar et al. (2009) reported that *Trichoderma* had diverse chemical nature and may supress weeds growth and development by secretion of toxic compounds (Atehnkeng et al., 2008; Gilardi et al., 2008; Mukherjee et al., 2012). Imran (2018) revealed that Trichoderma strains are known to induce resistance in plants and tolerate parasitic weeds. There are three classes of compounds that are produced by Trichoderma and induce resistance in plants are now known. These compounds induce ethylene production, hypersensitive responses and other defense related reactions in plant cultivars.

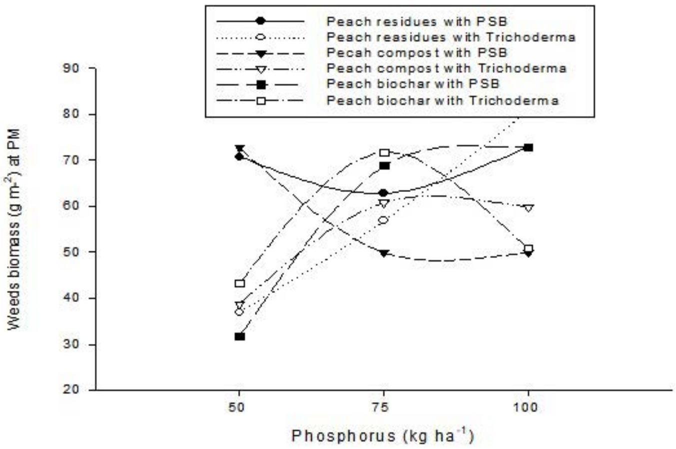

Figure 6: *Interaction among organic sources, phosphorus level and beneficial microbes for weeds biomass at physiological maturity of soybean.*

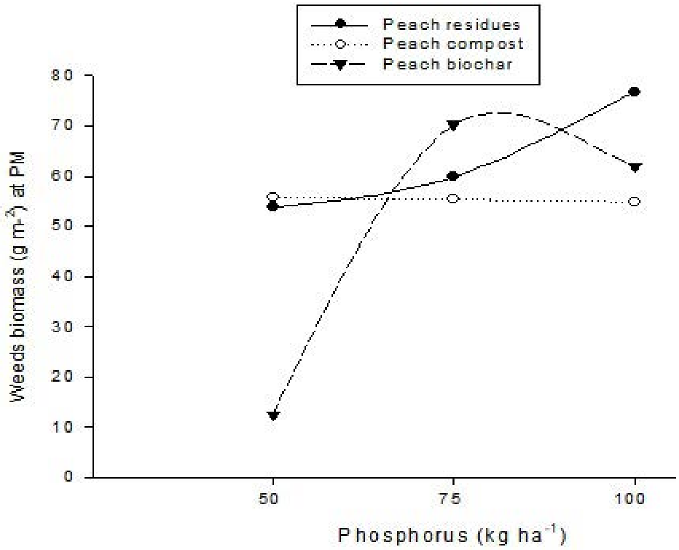

Figure 7: *Interaction between organic sources and phosphorus level for weeds biomass at physiological maturity of soybean*

Economic evaluation

Profitability and economic analysis was done for organic sources, P levels and beneficial microbes independently considering the prevailing cost incurred.

Profitability of phosphorous

In year one, maximum net returns in PKRs 72,521 ha^{-1} were attained by soybean plots treated with 100 kg P ha^{-1} followed by 75 kg P ha^{-1} (PKR 65,366 ha^{-1}), whereas minimum (31,272 PKR ha^{-1}) was with 50 kg ha^{-1} (Table 4). The VCR was higher in 75 kg P ha^{-1} treated plots (8.30) followed by 100 kg P ha^{-1} (6.91) and 50 kg P ha^{-1} was the least (5.96) among all the P levels. In year two; highest net returns (PKR 80,532 ha^{-1}) was achieved by P treated at the rate of

Table 4: *Profitability (PKR ha^{-1}) of soybean cultivation on account of incorporation of organic sources, phosphorus application and beneficial microbes (data pooled for two years).*

Treatment	Seed value	Soybean straw value	Total value	Cost of respective treatment	Increase over control	Net returns	Value cost ratio*
Phosphorus levels							
Control	51977	22607	74584				
50 kg ha^{-1}	87867	22547	110414	5250	35830	30580	5.8
75 kg ha^{-1}	119552	27366	146918	7875	72334	64459	8.2
100 kg ha^{-1}	132389	29223	161612	10500	87028	76528	7.3
Organic sources							
Control	51977	22607	74584	-	-	-	-
Peach Residues	101232	23780	125012	8880	50428	41548	4.67
Peach Compost	119859	25858	145717	10965	71133	60168	5.48
Peach Biochar	118717	29499	148216	11550	73632	62082	5.37
Beneficial microbes							
Control	51977	22607	74584	-	-	-	-
PSB	107141	25418	132559	5280	57975	52695	9.98
Trichoderma	119397	27340	146737	4700	72153	67453	14.35

*Retail price of 1 kg soybean grain in PKRs: 56.00; Retail price of 1 kg soybean straw in PKRs: 04.00; Residues cost in PKRs: 8,250 and 9,510; Compost cost in PKRs: 10,440 and 11,490; Biochar cost in PKRs: 10,800 and 12,300 was in each year of study (2016 and 2017); Price for 1 kg phosphorous in PKRs: 105; Price of Trichoderma for 1 hectare in PKRs: 4,700; Price of PSB for 1 hectare in PKRs: 5,280; * Value cost ratio determined using net returns values.*

100 kg P ha^{-1} followed by P at the rate of 75 kg ha^{-1} (PKR 63,550 ha^{-1}) and minimum (PKR 29,887 ha^{-1}) with 50 kg ha^{-1}. Highest VCR value was given by 75 kg P ha^{-1} followed by 100 kg P ha^{-1} (7.67). When combined over the two years, maximum net returns (PKRs 76,528 ha^{-1}) were gained with P at the rate of 100 kg ha^{-1} followed by 75 kg P ha^{-1} (PKRs 64459 ha^{-1}), although least (PKR 30580 ha^{-1}) were with 50 kg P ha^{-1}. The least value cost ratio with lowest P rate (5.8) was reasonably increased to 8.2 as P levels increased to 75 kg ha^{-1} and then decreased to 7.3 at 100 kg P ha^{-1}. Similar results are reported by many researchers (Atehnkeng et al., 2008; Gilardi et al., 2008; Mukherjee et al., 2012; Imran, 2018).

Profitability of organic sources

Highest net returns and value cost ratio for seed in year one were obtained with peach biochar having value in PKRs 69,586 ha^{-1} and 6.44 followed by peach compost PKR 59,126 ha^{-1} and 5.66, respectively (Table 4). The lowest net returns (PKR 34,583 ha^{-1}) and VCR (4.19) were associated with peach residues. In year two, maximum net returns (PKR 40,167 ha^{-1}) and value cost ratio (3.5) were obtained with peach compost followed by peach biochar with net returns (PKR 33,535 ha^{-1}) and value cost ratio (2.73). Minimum net returns (PKR 27,473 ha^{-1}) were recorded by peach residues, but value cost ratio was slightly higher (2.89) than peach residues. When combined over the two years, net returns (PKR 62,082 ha^{-1}), were highest in peach biochar followed by peach compost (PKR 60,168 ha^{-1}), whereas least net returns (PKR 41,548 ha^{-1}) were with peach residues. The VCR was highest in peach compost amendment (5.48) among the organic sources followed by peach biochar (5.37), while the least (4.67) in peach residues incorporated plots. Many worker indicated that farmer income could be enhanced with integrated fertilization (Yedidia et al., 2003; Harman, 2006).

Profitability of beneficial microbes

Economic analysis brought out that net returns (PKR 67,248 ha^{-1}) were higher with *Trichoderma* inoculated plots followed by PSB (PKR 51295 ha^{-1}) in year one (Table 4). The value cost ratio (VCR) was greater with *Trichoderma* inoculation (14.31) than PSB (9.71). In year two, maximum net returns were attained with *Trichoderma* (PKRs 67655 ha^{-1}) followed by PSB (PKR 54,095 ha^{-1}). Greater VCR (14.39) was gained with *Trichoderma* inoculation tailed by PSB (10.25). When combined over the two years, average pronounced net returns (PKR 67,453 ha^{-1}) were attained with *Trichoderma* followed by PSB (PKR 62,695 ha^{-1}). Comparison of average value cost ratio of both years revealed greater value (14.35) with *Trichoderma* followed by PSB (9.98). These results were supported by Imran et al. (2016) who revealed that farmer's income enhanced with growing off season vegetable along with seed inoculation.

Conclusions and Recommendations

On the basis of economic analysis, value cost ratio for peach biochar (5:1), P at 75 kg ha^{-1} (8:1) and soil application of *Trichoderma* (14:1) produced highest net incomes and suggested that application of *Trichoderma* along with peach biochar reduce weeds growth, development and density and could improve net income and profitability. It be situated to consider impending investigation studies allied to weeds biocontrol prospective of *Trichoderma* under field condition.

Novelty Statement

This research work is done for the first time in Pakistan and will ena-ble the farmers to enhance soil health, crop productivity and weeds suppression through peach waste management with application of bio fertilizers and inorganic phosphorus application.

Author's Contributions

Imran: Conducted research, manuscript write up, data collection, analysis and interpretation.
Amanullah: Chairman Supervisory committee of this research and timely guidance.
Muhammad Arif: Major member of Supervisory committee and supervision of this research work
Zahir Shah: Member of this research work and supervision related to soil work.
Abdul Bari: Co-supervisor.

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