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Effect of fungicides and bioagents on physico-chemical properties of soil under soybean (*Glycine Max* L. Merrill) Crop

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Abstract
In order to evaluate the effect of fungicides and bioagents on physico-chemical properties of soil under soybean crop, a field experiment was conducted during *Kharif* season of 2016 at Norman E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar. The results showed that the seed treatment through fungicides and bioagents cause non significant change in the soil pH and bulk density while there was significant change in the organic carbon content. Significant increases were also recorded for the available nitrogen and potassium content at harvest. The application of *Pseudomonas fluorescens* gave maximum amount of available N (275.13 kg/ha) and available K (141.81kg/ha). There was a non-significant numerical increase in available phosphate content which ranged from 20.13 to 26.97 kg/ha. It is concluded that the seed treatment through fungicides predispose the soils to overcome nitrogen, phosphorus and potassium (N, P and K) deficiencies. Among the fungicides and bioagents tested, the stimulation was more pronounced with *Pseudomonas* followed by formulated Mancozeb.

Keywords: Fungicides, bioagents, *Pseudomonas, Trichoderma viride*

Introduction
Nowadays, variegated fungicides with a broad range of physic-chemical properties are used to protect crops against fungal plant pathogens in agricultural practices and to sustain high crop production in modern agriculture. Fungicides have been an impediment to development of sustainable agriculture. Employment of biofertilizers and biopesticides may be able to side-step some of the deleterious effects caused by chemical fertilizers. Fungicides are applied in various ways; either through foliar application or through seed treatment. They may directly or indirectly enter to soil system and affect the soil physic-chemical properties. Although fungicides mainly target the pathogenic microorganisms but extensive use of these chemicals often lead to change in soil quality. Depending upon the chemical composition of these fungicides, the change may be negative or positive. Soybean (*Glycine max* (L.) Merrill) is one of the important major, profitable oil seed crop grown in the tropical, subtropical and temperate climates. It has a distinguished place among modern agricultural commodities as the world's most important seed legume and it contributes about 25 per cent to the total global edible oil. Alike other leguminous crop, it is a common practice in soybean to use fungicides through seed treatment. Commercial fungicides namely Mancozeb, Thiram, Captan, Carbendazim etc are widely used for control of fungal pests in agricultural crops like soybean. So far little information is available on the exact mechanism and fungicides behavior towards soil quality. The objective of this study was to assess the effect of different fungicides and bioagents on some major soil physicochemical properties.

Materials and Methods
A field experiment was conducted during *Kharif* season of 2016 at Pantnagar to study the effect of selected fungicides and bioagents on soil physic-chemical properties in soybean variety PS 1347. The soil of the experimental site was silty clay loam of pH 7.4 having 0.87% organic carbon, 192 kg/ha available nitrogen, 24.6 kg/ha available phosphorus and 160.16 kg/ha available potassium. The experiment was conducted in randomized block design with three replications in 5 x 3.6 m^2 plots. Soybean seed (PS 1347 variety) was sown @ 80 kg/ha with a spacing of 45 cm between rows, at 5cm depth.
The crop was uniformly fertilized with a basal dose of nitrogen (urea), phosphorus (SSP) and potassium (MOP) at 20, 60, 40 kg ha-1, respectively at the time of sowing. Plant population was maintained to 40 plants per square meter area. Soybean seed was treated with different

fungicides. Seed inoculation of *Bradyrhizobium japonicum* culture was done in all the treatments uniformly. There were fourteen treatments i.e. Control (T_1), Carbendazim @ 1.5 g/kg seed (T_2), Mancozeb @ 2.5 g/kg seed (T_3), Thiram @ 2.5g/kg seed (T_4), Captan @ 2.0 g/kg seed (T_5), *Pseudomonas fluorescens* @ 5g/kg seed (T_6), *Trichoderma viride* @ 5g/kg seed (T_7), Carbendazim+Mancozeb @ 3g/kg seed (T_8), Carbendazim+Thiram @ 3g/kg seed (T_9), Carbendazim+Captan @ 3g/kg seed (T_{10}), Mancozeb+Thiram @ 4g/kg seed (T_{11}), Mancozeb+Captan @ 4g/kg seed (T_{12}), Thiram+Captan @ 4g/kg seed (T_{13}), *Pseudomonas fluorescens* + *Trichoderma viride* @ 5g/kg seed (T_{14}).

The soil physic-chemical parameters such as pH, organic carbon, bulk density, available nitrogen, phosphorous, potassium were studied from the soil sample collected after harvest. Soil pH was measured at 1:1.25 soil to water ratio in systronics digital pH meter with calomel glass electrode assembly. The bulk density was calculated as the ratio of mass of soil to its total volume (Veihmeyer and Hendrickson, 1948). Soil organic carbon was assessed as per the methods prescribed by Walkley and Black (1934). Available nitrogen was determined by the method proposed by Subbiah and Asija (1956). Potassium was measured by flame photometer (Jackson, 1973). The method of Olsen *et al.* (1954) was used to measure phosphorous.

Results and Discussion

Effect of fungicides and bioagents on soil physico-chemical properties

Application of fungicides through seed treatment did not have significant effect on the soil bulk density and pH after harvest of crop (Table 1). The use of most of fungicides and bioagents did not significantly affect the soil organic carbon content. However, the treatments having Thiram (T_4) and Carbendazim+Thiram (T_9) significantly increased soil organic carbon over control treatment.

Soil properties are directly related with soil productivity, health and quality. Various physico-chemical properties of soil were taken under observation to visualize the effect of different fungicides and bioagents on soil. The bulk density of soil was not affected significantly due to application of fungicides. The slight reduction in EC and slight increase in pH of soil with the application of fungicides may be due to reduction in the salt concentration depending upon the chemical composition of fungicides. Similar observation was registered by Akinnfesi *et al.* (2006), who observed that fungicide residue cause significant increase in the soil pH and organic carbon.

Table 1: Effect of fungicides and bioagents on bulk density (BD), pH and organic carbon (%) of soil at harvest.

Treatments		BD (Mg m^{-3})	pH	Organic Carbon (%)
T_1	Control	1.32	7.25	0.82
T_2	Carbendazim @ 1.5 g/kg seed	1.33	7.26	0.84
T_3	Mancozeb @ 2.5 g/kg seed	1.33	7.25	0.84
T_4	Thiram @ 2.5 g/kg seed	1.32	7.25	0.85
T_5	Captan @ 2.0 g/kg seed	1.33	7.26	0.81
T_6	*Pseudomonas fluorescens* @ 5 g/kg seed	1.32	7.25	0.82
T_7	*Trichoderma viride* @ 5g/kg seed	1.32	7.26	0.81
T_8	Carbendazim+Mancozeb @ 3g/kg seed	1.32	7.26	0.83
T_9	Carbendazim+Thiram @ 3g/kg seed	1.32	7.25	0.85
T_{10}	Carbendazim+Captan @ 3g/kg seed	1.32	7.26	0.84
T_{11}	Mancozeb+Thiram @ 4g/kg seed	1.32	7.26	0.81
T_{12}	Mancozeb+Captan @ 4g/kg seed	1.31	7.26	0.80
T_{13}	Thiram+Captan @ 4 g/kg seed	1.32	7.25	0.83
T_{14}	*Pseudomonas fluorescens+Trichoderma viride @ 5g/kg seed*	1.33	7.25	0.81
CD (p=0.05)		NS	NS	0.02

Effect of fungicides and bioagents on available nutrients in soil

Available N

All the treatments with fungicides significantly increased available N in soil except Mancozeb + Thiram (T_{11}) and *Pseudomonas fluorescens* + *Trichoderma viridie* (T_{14}). The available N in soil ranged from 238.52 to 275.13 kg/ha. All the treatments except Thiram (T_4), Carbendazim + Mancozeb (T_8), Carbendazim + Captan (T_{10}) and Mancozeb + Thiram (T_{11}) with fungicides significantly increased available N content in soil in comparison to combined use of *Pseudomonas fluorescens* + *Trichoderma viridie* (T_{14}). The application of *Pseudomonas fluorescens* (T_6) gave maximum amount of available N (275.13 kg/ha), which was significantly higher than all the treatments except Mancozeb (T_3).

Available P

The data on available P in soil indicated that there was an increase in available P content of soil with the use of fungicides; however, the increases were non- significant. The available P content in soil ranged from 20.13 to 26.97 kg/ha. The highest content of available P in soil was recorded with the use of *Pseudomonas fluorescens* (T_6) followed by Mancozeb (T_6) while the lowest P content of 20.09 kg/ha was found with the use of *Trichoderma viridie* (T_6).

Available K

The data clearly indicated significant effect of fungicides on the available K in soil at harvest. All the fungicides treatment significantly increased available K in soil ranging from 126.98 to 141.81 kg/ha. The use of *Pseudomonas fluorescens* (T_6) registered maximum content of available K (141.81 kg/ha) followed by Mancozeb (T_3) which are significantly higher than other fungicide treatments. Among fungicide treatments the combined use of Mancozeb + Thiram (T_{11}) showed lowest amount of available K in soil.

The available nitrogen, phosphorus and potassium in soil increased with application of fungicides through seed treatment (Table 2, Fig. 1). This might be due to the fact that degeneration of the soybean nodules and roots takes place in soil after harvest which enhanced the content of available nutrients in soil. These findings are in close proximity with the findings of Wainwright and Pugh (1973) who also observed that when fungicides applied at field rate, the level of exchangeable NH_4^+-N and K were generally increased in

comparison to control. Application of *Pseudomonas fluorescens* @ 5g/kg seed resulted in highest available nitrogen, phosphorus and potassium over control treatment. This might be due to solubilization of inorganic P or mineralization of organic P by the action of organic and inorganic acids secreted by PSB in which hydroxyl and carboxyl groups of acids chelate cations like Al^{3+}, Fe^{3+}, Ca^{2+} (Kpomblekou and Tabatabai, 1994; Stevenson, 2005). Similar results were obtained by Pal (1997) who observed that available nitrogen and phosphorus content increased due to use of phosphorus solubilizing bacteria. This effect was mainly due to solubilization of phosphorus by *Pseudomonas.*

Table 2: Effect of fungicides and bioagents on available N, P and K in soil at harvest

Treatments		N (kg/ha)	P (kg/ha)	K (kg/ha)
T_1	Control	238.52	20.13	120.78
T_2	Carbendazim @ 1.5 g/kg seed	256.50	24.53	135.54
T_3	Mancozeb @ 2.5 g/kg seed	269.58	26.06	141.12
T_4	Thiram @ 2.5 g/kg seed	251.59	22.78	129.18
T_5	Captan @ 2.0 g/kg seed	255.85	23.75	128.85
T_6	*Pseudomonas fluorescens* @ 5 g/kg seed	275.13	26.97	141.81
T_7	*Trichoderma viride* @ 5g/kg seed	260.75	22.09	133.19
T_8	Carbendazim+Mancozeb @ 3g/kg seed	255.04	23.12	127.89
T_9	Carbendazim+Thiram @ 3g/kg seed	258.13	25.26	131.93
T_{10}	Carbendazim+Captan @ 3g/kg seed	252.43	22.82	127.22
T_{11}	Mancozeb+Thiram @ 4g/kg seed	249.25	22.58	126.98
T_{12}	Mancozeb+Captan @ 4g/kg seed	258.08	24.22	131.45
T_{13}	Thiram+Captan @ 4 g/kg seed	256.45	24.29	132.08
T_{14}	*Pseudomonas fluorescens+Trichoderma viride @ 5g/kg seed*	242.85	22.12	135.23
CD (p=0.05)		12.25	NS	5.28

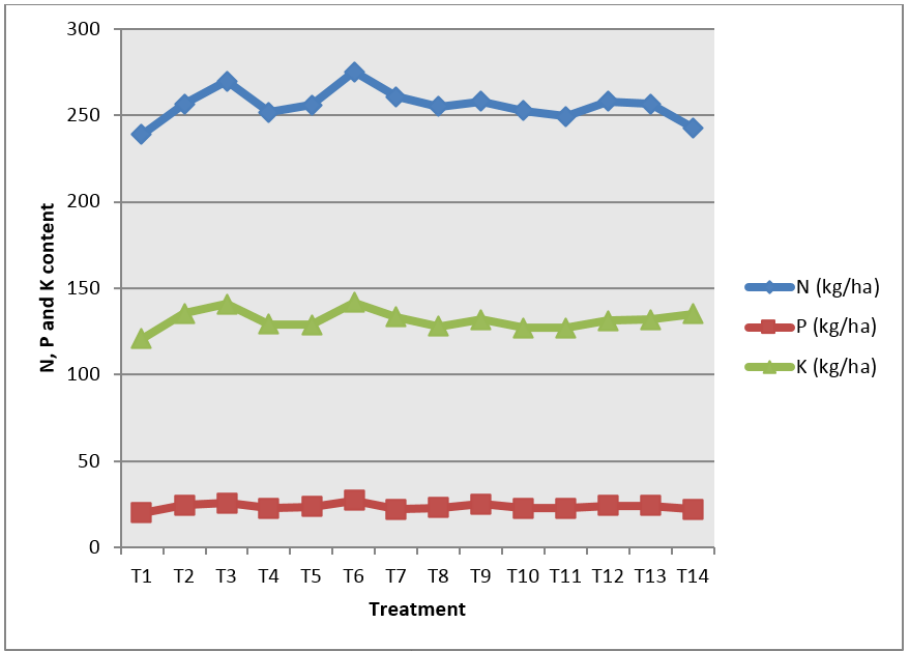

Fig 1: Effect of fungicides and bioagents on available N, P and K content in soil

Conclusion

The use of fungicides at recommended field rate through seed treatment did not alter the physical characteristics of the soil such as bulk density and pH. However, the chemical characteristics of the soil such as organic carbon, available nitrogen, phosphorus and potassium content were significantly affected by the use of fungicides and bioagents which resulted in the higher uptake of these nutrients by the crop. Among the fungicides and bioagents, *Pseudomonas* comparatively performed well in different parameters under study. So, it is concluded from the present study that most of the fungicides used at recommended dose through seed treatment are not harmful for the crop and soil.

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