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Effect of Organic Manures and Microbes on *Striga asiatica* (L.) Kuntze Management in Kodo Millet

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A B S T R A C T

Kodo millet (*Paspalum scrobiculatum* L.), a nutritious coarse cereal is vulnerable to partial root parasite *Striga asiatica* in low fertile soils and may be resulted in economic yield loss. Reduction in *Striga* related parameters was recorded in kodo millet using organic fertilizers enriched with microbes *in Vivo*. Soil application of farm yard manure (FYM) and vermi-compost (VC) enriched with *Trichoderma* spp., *Azospirillum* spp. and *Glomus intraradices* significantly reduced the emerged *Striga* count plot^{-1} (NS), *Striga* vigour ratings (SVR), *Striga* severity (SS) and value of area under *Striga* number progress curve (ASNPC) in kodo millet. Reduction ranging from 60.2 to 79.5% in NS, 70.6 to 92.2% in SS and an increase of 14.0 to 54.2% in grain yield ha^{-1} was recorded in different treatments. Lowest values of NS, SVR, SS and ASNPC were recorded in application of 100% recommended dose of fertilizers i.e. 40: 20 : 0 kg NPK ha^{-1}. Among the treatments of organic fertilizers enriched with microbes, lowest value of NS, SVR, SS and ASNPC were recorded in soil application of FYM (2.5 t ha^{-1}) + VC (1.25t ha^{-1}) enriched with *Trichoderma* + *Azospirillum* @ 2 kg/tones of manure closely followed by application of FYM (2.5 t ha^{-1}) + VC (1.25t ha^{-1}) enriched with *Trichoderma* @ 2 kg/tones of manure before sowing and both the treatments were at par. Maximum grain yield was also recorded in the same treatments.

Introduction

Kodo millet (*Paspalum scrobiculatum* L) is a hardy small seeded cereal crop, generally grown by poor farmers in low fertile lands with low or no cash inputs for their own consumption. The grains are nutritionally as well as medicinally rich and recommended for diabetic patients. In India, Madhya Pradesh ranks first in area of kodo millet, where the crop is cultivated in 143.47 thousand hectares with average yield of 525.5 kg ha^{-1} (www.landrecords.mp.gov.in). Among the biotic stresses, partial root parasitic flowering plant, *Striga* species popularly known as *witch weed* is a major constraint and a serious threat to subsistence kodo millet production particularly in light and low fertile soils by withdrawal of water, nutrients and assimilates. *Striga* damage is associated with degraded environments and is most severe in subsistence farming system. In India, few species of *Striga* namely *S. asiatica*, *S. hermonthica*, *S. lutea* and *S. densiflora* were reported to cause devastating yield losses in coarse cereals particularly in kodo millet (Kumar, 1940, Jain and Tripathi, 2002), finger millet (Srinivasan, 1947), foxtail millet (Kumar and Solomon, 1941, Srinivasan, 1947), pearl millet (Kumar and Solomon, 1941, Porwal, 1975), sorghum (Sarmiso, 2016), maize (Gacheru and Rao, 2001). In a roving field survey, *Striga* incidence ranging from 0.0 to 17.5% with higher frequency of *Striga* infestation varied from 66.7 to 100.0% was recorded in 7 districts of Madhya Pradesh during the year 2005 to 2011 by Jain *et al.*, (2016) in farmer's field. Resistance in kodo millet cultivars against *Striga* species were reported by Reddy and Dastagiraiah (1987) and Jain *et al.*, (2018). Advance research on *Striga* control was reviewed by Teka (2014) and suggested that integrated *Striga* management strategies are the suitable approach against this noxious root parasite. Use of organic and inorganic fertilizers, AM fungi, herbicides and biological control has been recommended to reduce *Striga* damage in cereal crops. Hence, in the present investigation, attempts have been made to study the effect of organic manures and microbes on *Striga asiatica* (L.) Kuntze management in kodo millet.

Materials and Methods

A field experiment was conducted using two organic manures i.e. farm yard manure (FYM) and vermicompost (VC) along with three microbes namely *Trichoderma viride*, *Azosprilillum* spp. and *Glomus intraradices* (VAM) in various combinations at experimental area of College of Agriculture, Rewa (M.P.) during *Kharif* 2015. The experiment was laid out in randomized block design with three replications in a plot size of 3.0 x 1.5 m with 22.5 cm row to row and 7.5 cm plant to plant spacing. *Striga* sand mixture (1:39) was applied @ 15 g plot^{-1} 10 days before sowing of a susceptible Kodo millet variety GPUK 3. Microbes were mixed in FYM / Vermicompost (table 1), incubated for 15 days and then applied in the soil at the time of sowing.

Application of 100% recommended dose of fertilizers (RDF) along with two controls namely non-infested with *Striga* and infested with *Striga* were also maintained for comparison. *Striga* related parameters namely number of emerged *Striga* plant plot^{-1} (NS), *Striga* vigour ratings (SVR), *Striga* severity (SS) and area under the above ground *Striga* number progress curve (ASNPC) were recorded in each plot at dough stage. SVR was scored per row on a scale of 0-9 depending on height and number of branches in *Striga* plant (Haussman *et al.*, 2000).

Striga vigour rating (0- 9 scale)

Grade	*Striga* plant
0	no emerged *Striga* plants
1	average height of *Striga* plants 5 cm without branches,
2	average height of *Striga* plants 6 – 20 cm without branches ,
3	average height of *Striga* plants 6-20 cm with branches,
4	average height of *Striga* plants 21 - 30 cm with 5 branches,
5	average height of *Striga* plants 21 – 30 cm with > 5 branches,
6	average height of *Striga* plants 31 - 40 cm with 10 branches,
7	average height of *Striga* plants 31 - 40 cm with > 10 branches,
8	average height of *Striga* plants > 40 cm with 10 branches and
9	average height of *Striga* plants > 40 cm with > 10 branches

Striga severity (SS) was calculated for each treatment by multiplying number of emerged *Striga* plant with *Striga* vigour ratings (Rodenburga *et al.*, 2005). Area under *Striga* number progress curve (ASNPC) is a measure of the total Striga emergence throughout the season in each treatment and was calculated as per formulae outlined by Haussman *et al.*, (2000).

$$\text{ASNPC} = \sum_{i=0}^{n-1}\left[Si + \frac{S(i+1)}{2}\right](t(i+1) - ti)$$

Where,

n is the number of *Striga* assessment dates, Si is the *Striga* number at i^{th} assessment date and Ti is the days after sowing at i^{th} assessment.

Yield and yield contributing traits namely plant height (cm), leaves plant^{-1}, leaf area (cm^2), panicles weight plant^{-1} (g), and fresh weight as well as dry weight of kodo millet plant was recorded in each treatment. Grain yield plot $^{-1}$ (g) was recorded at maturity and converted into kg/ha. Relative grain yield increment (GYI) over control was calculated using the following formula.

$$\text{GYI (\%)} = \frac{\text{Grain yield in a treatment} - \text{Grain yield in control}}{\text{Grain yield in control}} \times 100$$

The data were analyzed statistically in randomized block design using software WASP-1. The treatments were compared by least significant differences at 5% probability levels.

Results and Discussion

The results pertaining to the effect of organic fertilizers enriched with *Trichoderma*, *Azospirillium* and *Glomus intraradices* (VAM) along with inorganic fertilizers on *Striga* related parameters, yield contributing traits and grain yield are presented in Table 1& Table 2.

Striga related parameters

Data presented in Table 1 related significant difference in emerged *Striga* count per plot (NS) in different treatments ranging from 0.0 to 20.0 with an average of 16.7. Minimum NS was recorded in application of 100 per cent RDF (T9) i.e. 40:20:0 Kg NPK per hectare (10.3) followed by application of FYM (2.5 t per hectare)+ vermin-compost (1.25 t per hectare) enriched with *Trichoderma* + *Azospirillum* @ 2 Kg /tones of manure (T7), application of FYM (2.5 t ha^{-1}) + VC (1.25t ha^{-1}) enriched with *Trichoderma* @ 2 kg/tones of manure (T5), vermi-compost (VC) @ 2.5 t/ha enriched with *Trichoderma* @ 2 kg/tones of manure (T3) and application of VC@ 2.5 t/ha enriched with *Glomus intraradices* (T8). Reduction in NS ranged 60.2 to 79.5% was maximum in T_9 followed by T_7 and T_5. *Striga* severity (SS) ranged 0.0 to 280.8 in different treatments. Lowest SS was noted in T_7 followed by T_9, T_5 and T_3. Reduction in SS was 70.6 to 92.2% in different treatments. Maximum reduction in SS was recorded in T_7 closely followed by T_9 and T_5. *Striga* vigour ratings (SVR) ranged 0.0 to 5.4 in various treatments. Lowest SVR was recorded in T_7 followed by T_9. Values of area under *Striga* number progress curve (ASNPC) varied 0.0 to 428.0 in different treatments was minimum in T_7 (147.0), followed by T_9 (151.3) and T5 (154.2). Overall, *Striga* related parameters were lowest in T7, closely followed by T_9 and T_5. These treatments were found to reduce the *Striga* infestation in Kodo millet.

Yield and yield contributing traits

The results of grain yield and its contributing traits presented in Table 2 revealed significant variation in plant height (cm), leaves plant^{-1}, leaf area (cm^2), panicle weight plant^{-1}, fresh weight and dry weight of kodo millet plant among the treatments. Plant height varied from 36.7 to 47.5 cm was maximum in application of 100 per cent RDF (T9) and was at par in all the treatments except control non-infested with *Striga* (T10) and application of vermicompost (VC) @ 2.5 t/ha enriched with *Azospirillum* @ 2 kg/tones of manure (T_4). Leaves plant^{-1} varied 11.7 to 18.6 with maximum number in T_7 closely followed with T_6, T_5, T_9 and T_8. Leaf area (LA) was significantly influenced and ranged 16.8 to 24.5 cm^2 in different treatments. Maximum LA was estimated in T_9, which was at par in T_7, T_5, T_6 and T_8. Panicle weight plant^{-1} ranging from 3.02 to 4.82 g was highest in T_5 followed by T_7, T_9 and T_3. Fresh weight and dry weight of kodo millet plant was recorded highest in T_7 and were at par in T_9, T_8 and T_5. Grain yield (kg ha^{-1}) of kodo millet in different treatments ranged from 663.0 to 1022.2 kg ha^{-1}. It was highest in T_7 and statistically at par in the treatments of T_9, T_6, T_5, T_3 and T_8. An increase of 12.8 to 54.2% in grain yield was recorded in different treatments. Maximum grain yield increment over control was recorded in application of FYM (2.5 t ha^{-1}) + VC (1.25t ha^{-1}) enriched with *Trichoderma* + *Azospirillum* @ 2 kg/tones of manure (T_7) followed by application of 100% RDF (T_9).

Organic manures contain high amount of nitrogen that could be used to reduce *Striga* infestation by the mechanisms of reduction in stimulant exudation from host roots. Esliba *et al.*, (2000) reported that a combination of 40 kg N ha^{-1} and FYM @ 10, 20 and 30 t ha^{-1} reduced *Striga* emergence and improved grain yield as compared to control in sorghum and maize. Dzomeku and Amegbor (2013) reported 80% suppression in emergence of *S. hermonthica* infesting maize by using organic manure and neem powder. Osman *et al.*, (2013) observed reduced emergence of *S. hermonthica* infecting maize in the treatment of organic fertilizers EIkhairat (mixture of plant residues) and EIkhaseeb (mixture of sheep manure, FYM and chicken in 1:2:1 ratio) alone and enriched with phosphorin (*Bacillus megatherium* var. *phosphacticum*). However, application of *Azospirillum brazilence* with organic fertilizers was not found effective to reduce *Striga* emergence. Effectiveness of *Tichoderma harzianum* and *T. viride* was reported against phanerogamic root parasites like *Striga* (Hassan *et al.*, 2013 and Boari *et al.*, 2016) and orobanche (Abdel kader and EI- Mougy, 2009). Boari *et al.*, (2016) reported that *T. harzianum* and *Fusarium oxysporum* reduces the strigalactone (SL) content, which is responsible for *Striga* seed germination. These microorganisms act as a physiological barrier by preventing the germination of *Striga* seeds through the ability to biotransform the stimulatory signals. Contribution of AM fungi play key ecological role in nutrient acquisition, disease prevention and soil aggregate formation. Gworgwor and Weber (2003) reported that AM fungi *Glomus mosseae* significantly reduced the number of *Striga* emerging plant (*S. hermonthica*), increased plant growth, shoot and total dry matter and yield of sorghum. Maximum root colonization of sorghum by AM fungi was in *G. mosseae* (44%) and G. *intraradices* (24%). Lendzemo *et al.*, (2005) also suggested that *Striga* performance in the presence of AM fungi was negatively impacted with reduced and / or delayed germination and attachment with the host roots. Significant reduction in the number of *S. hermonthica* shoot in sorghum (> 50%) and maize (30%) along with dry weight of *Striga* with AM fungal inoculation was recorded. Othira *et al.*, (2012) also reported that AMF (*Glomus* spp.) inhibit the germination and reduces the growth of *S. hermonthica*, where as enhance the growth and development of maize. All these reports corroborate the present findings.

Table.1 *Striga* related parameters as influenced by organic fertilizers and microbes in kodo millet

Treatment Code	Treatment details	*Striga* count plot^{-1} (NS)	Relative reduction (%) in NS	*Striga* severity (SS)	Relative reduction (%) in SS	*Striga* vigour rating (0-9)	Area under *Striga* number progress curve (ASNPC)
T_1	Application of FYM @ 5 t/ha enriched with *Trichoderma* @ 2 kg/tones of manure	15.7 (1.210)	68.8	58.9	79.0	3.8	259.5
T_2	Application of FYM @ 5 t/ha enriched with *Azospirillum* @ 2 kg/tones of manure	20.0(1.316)	60.2	82.5	70.6	4.2	396.2
T_3	Application of Vermicompost (VC) @ 2.5 t/ha enriched with *Trichoderma* @ 2 kg/tones of manure	13.3(1.145)	73.5	46.8	83.3	3.5	299.2
T_4	Application of Vermicompost (VC) @ 2.5 t/ha enriched with *Azospirillum* @ 2 kg/tones of manure	17.7(1.259)	64.8	76.6	72.7	4.3	373.7
T_5	Application of FYM (2.5 t ha^{-1}) + VC (1.25t ha^{-1})enriched with *Trichoderma* @ 2 kg/tones of manure	11.3(1.078)	77.5	36.4	87.0	3.1	154.2
T_6	Application of FYM (2.5 t ha^{-1}) + VC (1.25t ha^{-1}) enriched with *Azospirillum* @ 2 kg/tones of manure	18.3(1.288)	63.6	67.1	76.1	3.6	354.5
T_7	Application of FYM (2.5 t ha^{-1}) + VC (1.25t ha^{-1}) enriched with *Trichoderma* + *Azospirillum* @ 2 kg/tones of manure	11.0(1.071)	78.1	21.9	92.2	2.0	147.0
T_8	Application of VC@ 2.5 t/ha enriched with Mycorrhizae (*Glomus intraradices*)	15.7(1.206)	68.8	60.3	78.5	3.8	337.7
T_9	Application of 100% RDF	10.3(1.057)	79.5	28.5	89.8	2.7	151.3
T_{10}	Control (Non-infested with *Striga*)	0.0 (0.000)	100.0	0.0	100.0	0.0	0.0
T_{11}	Control (infested with *Striga*)	50.3 (1.691)	0	280.8	0	5.4	428.0
	Mean LSD (5%)	16.7 (1.120) 0.185		69.1 79.278		3.3 0.896	263.8 232.5
Figures in parentheses are log transformed values							

Table.2 Yield and yield attributes of kodo millet as influenced by application of organic fertilizers and microbes.

Code	**Treatment details**	**Plant height (cm)**	**Leaves plant^{-1}**	**Leaf area (cm^2)**	**Panicle weight plant^{-1} (g)**	**Fresh weight of plant (g)**	**Dry weight of plant (g)**	**Grain yield Kg ha^{-1}**	**Grain yield increment over control (%)**
T_1	Application of FYM @ 5 t/ha enriched with *Trichoderma* @ 2 kg/tones of manure	42.3	14.4	18.1	3.92	6.51	3.42	774.1	16.8
T_2	Application of FYM @ 5 t/ha enriched with *Azospirillum* @ 2 kg/tones of manure	43.0	15.0	19.0	3.84	6.34	3.23	763.0	15.1
T_3	Application of Vermicompost (VC) @ 2.5 t/ha enriched with *Trichoderma* @ 2 kg/tones of manure	43.5	14.7	20.1	4.32	7.04	3.87	814.8	22.9
T_4	Application of Vermicompost (VC) @ 2.5 t/ha enriched with *Azospirillum* @ 2 kg/tones of manure	41.5	15.2	20.7	3.89	7.12	4.02	755.5	14.0
T_5	Application of FYM (2.5 t ha^{-1}) + VC (1.25t ha^{-1}) enriched with *Trichoderma* @ 2 kg/tones of manure	46.1	17.9	23.7	4.82	7.58	4.37	888.9	34.1
T_6	Application of FYM (2.5 t ha^{-1}) + VC (1.25t ha^{-1}) enriched with *Azospirillum* @ 2 kg/tones of manure	43.3	18.4	23.0	4.13	6.97	3.84	896.3	35.2
T_7	Application of FYM (2.5 t ha^{-1}) + VC (1.25t ha^{-1}) enriched with *Trichoderma* + *Azospirillum* @ 2 kg/tones of manure	46.5	18.6	24.5	4.71	8.07	4.64	1022.2	54.2
T_8	Application of VC@ 2.5 t/ha enriched with Mycorrhizae (*Glomus intraradices*)	44.3	17.0	21.4	3.94	7.48	4.38	803.7	21.2
T_9	Application of 100% RDF	47.5	17.8	24.6	4.36	7.69	4.63	1014.8	53.1
T_{10}	Control (Non-infested with *Striga*)	38.9	13.2	17.8	3.36	6.02	2.97	748.1	12.8
T_{11}	Control (infested with *Striga*)	36.7	11.7	16.8	3.02	5.02	2.79	663.0	0.0
	Mean	43.0	15.5	20.9	4.03	6.90	3.83	831.3	
	LSD (5%)	5.462	2.611	3.632	0.586	0.656	0.684	218.48	

It is concluded that soil application of FYM (2.5 t ha^{-1}) + VC (1.25t ha^{-1}) enriched with *Trichoderma* + *Azospirillum* @ 2 kg/tones of manure and soil application of FYM (2.5 t ha^{-1}) + VC (1.25t ha^{-1}) enriched with *Trichoderma* @ 2 kg/tones of manure before sowing were at par and found best for minimizing the infestation of *Striga asiatica* and obtaining maximum grain yield in kodo millet.

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