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Effect of Agri-horti Systems and Weed Management Practices on Growth and Yield of Finger Millet (*Eleusine coracana* L.)

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A B S T R A C T

Afield experiment was conducted during the *kharif* (rainy) season of 2018 at Agricultural Research Farm, Banaras Hindu University-South Campusin Eastern Uttar Pradesh of district Mirzapur in split plot design replicated thrice. The main factor consist of three agri-horti system i.e. [guava (*Psidium guajava*), bael (*Aegle marmelos*) and open field] while 6-weed management practices sub factor[2-HW (20 & 40 DAS), Oxyflourfen 0.1 kg a.i./ha (PE) *fb*clodinafop 60g a.i/ha (PoE), bispyribac-Na 20 g a.i./ha (early PoE), isoproturon 0.75 kg a.i /ha (PE) *fb*1-hand-weeding (30 DAS), pendimethalin 1.0 kg a.i./ha *fb*quizalofop-ethyl 0.04 kg/ha, 2-HW (20 & 40 DAS) and weedy check]. Application of 2-HW (20 & 40 DAS) and isoproturon 0.75 kg/ha (PE) *fb*1- HW (30 DAS) effectively manage the weeds vis-à-vis produced higher crop growth, yield attributes and yield of finger millet followed by oxyflourfen 0.1kg/ha (PE) *fb* clodinafop 60 g/ha (PoE), bispyribac –Na 20 g/ha (PoE) (15 DAS), pendimethalin 1.0 kg/ha (PE) *fb* quizalofop-ethyl 0.04 kg/ha (PoE).

Keywords

Agri-horti system, Finger millet, Herbicide and weed management

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Introduction

Finger millet is an important minor millet that is cultivated in India. It is a staple food crop in many of the country's hilly areas. This crop is grown at an altitude of 2100 meters above sea level. It is, in reality, the primary cereal crop for monsoon season in some hill region. It is cultivated for both grain and forage. In northern hills, grains are eaten mostly in the form of, chapattis, in south India grain are used in many preparations like cakes, puddings, sweets. Mandua grain contains 9.2 % protein, 1.29 %, 76.32 % carbohydrate, 2.24 % minerals, 3.90 % ash and 0.33 % calcium. It is good for persons suffering from diabetes. It is cultivated over an area of 2.65 million hectares with total production of about 2.9 million tonnes (Singh *et al.*, 2003).Finger millet is grown largely as drill sown crop under rainfed conditions and as transplanted crop under irrigation. Since, the crop has slow growth habit in the initial stages, the weeds possessing faster growth habit can avail of this situation and offer severe competition to the crop for light, nutrients and moisture (Kumar *et al.,* 2015) and (Ramachandra Prasad *et al.*, 1991 and Singh and Arya, 1999) found the critical period of weed competition in finger millet to be around 30 to 45 days after sowing and further delay in weed control leads to serious decrease in grain yield ranging from 34 to 61percent.Manual weeding (2-3), common practices for weed management in finger millet. Herbicides have been reported to be effective and economically feasible in the smallholder (Muoni *et al.,* 2013).

India's population is growing rapidly, while the size of an average farm holding is shrinking (Srinivasa Rao *et al.*, 2014). Now-a-days, it is a biggest challenge for a country to feed the burgeoning population, that too without horizontal expansion in land holding. In fact, in near future, in India the demand of cereals is projected to grow from current production of 261.8 million tons (FAO 2019) to 270 million tons in 2024-2025 (Srinivasa Rao *et al.*, 2014). Therefore, one of the ways for increasing the production of cereals is the utilization of inter-row spaces under agroforestry system for the introduction of annual cereals crops. Among the various categories of agro-forestry system, agri-horti system is most popular among the farmers, where the annual crops are grown simultaneously in the alley of the fruit-tree (Lundgren and Raintree, 1982; Nair, 1993).

The mechanical and cultural methods of weed control are no doubt effective; however, non-availability of labour and ever increasing labour cost due to rapid urbanization and industrialization farmers many a time experience severe labour shortage. Coupled with ever increasing cost of labour, it is uneconomical and difficult to employ these methods to control weeds was reported by Fischer *et al.*, (2001). The use of herbicides in controlling weeds has been proved successful in the advanced countries and is now gaining ground in Indian Agriculture, in view of labour scarcity and prohibitive wages. Under these situations the herbicides play an important role in weed management. However, it is essentially required that before introduction of any crop in between the alleys of agri-horti system it is utmost important to work out the compatibility of component species (annual crop and perennial tree), because many a time, due to negative interactions between the component species, the growth and yield of annual crop was seriously affected (Thapaliyal *et al.*, 2008).

Agroforestry has the potential to create a more integrated, diverse, productive, profitable, healthy, and sustainable land-use system (Sharma *et al.*, 2017). However, it is essentially required that before introduction of any crop in between the alleys of agri-horti system it is utmost important to work out the compatibility of component species (annual crop and perennial tree), because many a time, due to negative interactions between the component species, the growth and yield of annual crop was seriously affected (Thapaliyal *et al.*, 2008). Since, the crop has slow growth habit in the initial stages, the weeds possessing faster growth habit can avail of this situation and offer severe competition to the crop for light, nutrients and moisture (Kumar *et al.*, 2015) and (Prasad *et al.*, 1991 and Singh and Arya, 1999) found the critical period of weed competition in finger millet to be around 30 to 45 days after sowing and further delay in weed control leads to serious decrease in grain yield ranging from 34 to 61 percent. It was observed that species combinations and importance of weed communities differ with agroforestry system because; some studies have documented inhibitory allelopathic effects of trees on weed germination and growth (Kaur *et al.,* 2011). Therefore, one of the ways for increasing the production of cereals is the utilization of inter-row spaces under agroforestry system for the introduction of annual cereals crops. Among the various categories of agro-forestry system, agri-horti system is most popular among the farmers, where the annual crops are grown simultaneously in the alley of the fruit-tree (Lundgren and Raintree 1982, Nair 1993). This system not only helps in better utilization of land resources but also generates more employments and income as compared to sole cultivation of fruit trees. Actually, during the initial 6-7 years of agri-horti systems and even after that period, with proper pruning management, intercrop annual crops in agri-horti system produce good yield, without any significantly reduction (Kumar 2018).

Therefore, under the agro-climatic conditions of Vindhyan zone, there is good opportunity to introduce some millets as inter-crop in the alleys of agri-horti system. Millets are the most viable option in the dryland conditions as they require minimum water and can with stand in the adverse weather conditions (Chapke *et al.,* 2018) and can usher in food, feed, fodder, nutritional and livelihood security of the farmers. In fact, millet as also called as “Miracle Nutri-Cereals” providing nutritional and health security to all in dry land ecosystems. Among the various small millet grown in India, finger millet contributes nearly 80% of production and the remaining from kodo millet, little millet, foxtail millet, barnyard millet and proso millet in that order (IIMR, 2015).

Materials and Methods

Experimental site and soil

A field experiment was conducted during the *kharif* (rainy) season of Agricultural Research Farm, Banaras Hindu University-South Campus, 25º 10’ latitude, 82º 37’ longitude and an altitude of 147 meters above mean sea level, Mirzapur, Uttar Pradesh. The experimental field soil was sandy clay loam in texture, classified as Inceptisol (Typic Ustochrept), having slightly acidic (pH 5.7-6.4), low in nitrogen and organic carbon (0.29 %) whereas, medium in available P and K contents. The total rainfall received during crop season i.e. august to November growing period was 455.6 mm, out of which nearly 50 percent receive September.

Trial establishment

In split plot design, experiment was conducted involving three agri-horticultural system i.e. guava (*Psidium guajava*), bael (*Aeglemarmelos*) and open field in main plot and 6-weed management practices [Oxyflourfen 0.1kg a.i./ha (PE)*fb*clodinafop 60g a.i/ha (PoE), bispyribac-Na 20g a.i./ha (early PoE), isoproturon0.75 kg a.i /ha (PE) *fb*1-hand-weeding (30 DAS), pendimethalin 1.0 kg a.i./ha *fb*quizalofop-ethyl 0.04 kg /ha, 2-HW (20 & 40 DAS) and weedy check] were randomly allocated to subplots and replication three. Seed of finger millet (variety: VL Mandua 352) was sown at the rate of 6-8 kg/ha at 10 cm depth in open furrows made with a manual single row drill, having a row spacing of 23x10 cm and immediately covered with soil(Singh *et al.,* 2003).Crop was uniformly fertilized with urea, and DAP to supply 40kgN/ha and 40kg P_2O_5/ha, respectively. Pre-emergence (PE) herbicide applied within 2-day of sowing, whereas, early post emergence (PoE) and PoE was applied 20 and 30 DAS, respectively.

Before spraying, herbicides were dissolved in water at the rate of 500 L/ha and sprayed with a knapsack sprayer fitted with a flat-fan nozzle.

Biometrical observations

Various yield and straw yield parameters such grain yield (kg/ha), straw yield (kg/ha), biological yield, harvest index and total cost of cultivation, net return and gross return parameter were recorded. Weed density and biomass were recorded at 60 DAS, as per the procedure given by Singh and Saini (2008) as presented as number/m^2 and g/m^2, respectively. For estimation nitrogen (N), phosphorus (P) and potassium (K) uptake by green gram and weeds, first N, P, and K content in plant samples were determined. Nitrogen content in plant samples (crop and weeds) were estimated by micro-Kjeldahl method.

However, phosphorus was estimated colorimetrically following the vanadomolybdate method and potassium content in the aliquot of the triple acid extract was estimated by emission spectrophotometry using EEL flame photometer (Jackson, 1973).

Statistical analysis

Data collected on crop and weed growth statistically analysed as per procedure suggested by Gomez and Gomez, 1984. Heterogeneous weed (density and biomass) data were square-root transformed prior to analysis to produce a near normal distribution, although non transformed means are presented for clarity.

The treatment differences were tested by ‘F’ test of significance on the basis of null hypothesis. Critical differences were worked out at 5 per cent level of probability where ‘F’ test was significant.

Results and Discussion

Effect on weed growth

Data presented in table-3 showed that three agri-hortisystem is similar above the ground morphology (*i.e* tree height, canopy diameter, number of branches, crown length and girth). Most of the yield and economics parameter are non-significantly influenced with the agri-horti system. Further, open field showed lowest infestation of BLWs. The reasons for increased growth and yield parameters under open field might be due to several reasons, firstly, finger millet being a C4 crop for higher photosynthetic efficiency requires full sunlight for light saturation. It is hypothesized that under the alley cropping system, inter-row finger millet crop received reduced light due to shading effect of tress plantation, which would ultimately reduce the crop yield. Similarly, Reynolds *et al.,* (2007) also in view that the degree of light reduction from the agro-forestry tree species would depend on the tree species, it’s shape, height of crown and density of foliage. Further, they observed that C4 under-storey crop produced low yield due to reduced availability of light. Secondly, under open field condition due to higher light intensity there might be more uptake of nutrients due to enhanced activity of AM fungi, which may positively affect the various growth and yield parameters. Similarly, Shukla *et al.,* (2008) tested the growth response of different crops u0nder variable light intensity along with AM inoculation and results showed that the activity of AM fungi normally enhanced with higher light intensity (100 per cent) as compared to the low light intensity, which in turn increase the P-uptake by the plant. Thirdly, researches showed that many a time agro-forestry system exhibited negative allelopathic interactions which would adversely affect the crop growth and yield, however, these allelopathic interactions are absent under the open field situation (Thapaliyal *et al.,* 2008), thus results in higher yield.

Table.1 Influences of weed management practices on grain yield, straw yield and economic of finger millet

Treatment	Yield (kg/ha)			Harvest Index	Economics			
	Grain	Straw	Biological		Total cost of cultivation (`)	Gross return (`)	Net return (`)	B:C ratio
Agri-horti system								
Guava	2901.23b	5056.58a	7957.81b	36.48b	48454.43	205564.14	157109.71	4.24
Bael	2831.33c	3672.84b	6504.17c	43.40a	48981.82	195609.81	146628.00	3.99
Open field	3679.48a	4891.98a	8571.46a	43.60a	22691.77	114924.73	92232.96	5.06
SEm±	40.44	78.07	118.51	0.67	-	-	-	-
CD (P=0.05)	158.79	306.54	465.33	2.65	-	-	-	-
Weed management practice (W)								
Oxy *fb Clod*	3101.85b	4351.85b	7453.70c	41.89a	114459.0	512713.52	398254.51	4.48
Bis-Na	3306.28b	4526.75b	7833.03c	42.28a	112682.7	531298.57	418615.86	4.71
IP*fb* 1-HW	3522.02a	5318.93a	8840.95b	40.04a	127232.7	551495.40	424262.69	4.33
Pendi*fb*Quiza	2802.16b	3899.18c	6701.34d	41.88a	118948.7	485288.62	366340.41	4.08
2-HW	3786.01a	5833.33a	9619.34a	39.78a	136772.7	575769.08	438996.37	4.21
WC	2305.77c	3312.76d	5618.53e	41.09a	110672.7	440026.87	329354.16	3.98
SEm±	123.15	139.62	262.77	1.25	-	-	-	-
CD (P=0.05)	355.68	403.24	758.92	3.62	-	-	-	-
S*W	S	S	S	S	-	-	-	-

Table.2 Effect of agri-horti system and weed management practices on density and biomass grasses and BLWs in finger millet

Treatment	*Acalypha indica*		*Oldenlandia corymbosa*		*Eclipta alba*		*Anagallis arvensis*	
	Density (plant/m^2)	Biomass (g/m^2)	Density (plant/m^2)	Biomass (g/m^2)	Density (plant/m^2)	Biomass (g/m^2)	Density (plant/m^2)	Biomass (g/m^2)
	45 DAS	45 DAS	45 DAS	45 DAS	45 DAS	45 DAS	45 DAS	45 DAS
Agri-horti system								
Guava	2.68(8.89)a	2.96(11.56)a	3.89(22.78)a	3.86(22.19)a	2.46(9.72)b	2.57(10.57)a	3.42(14.72)a	4.10(21.89)a
Bael	0.71(0.00)b	0.71(0.00)c	0.71(0.00)b	0.71(0.00)b	0.71(0.00)c	0.71(0.00)b	2.99(12.50)b	3.52(18.85)b
Open field	1.96(5.28)a	1.89(0.07)b	3.77(22.22)a	3.87(24.16)a	3.23(15.28) a	3.17(15.61)a	0.71(0.00))c	0.71(0.00)c
SEm±	0.27	0.19	0.40	0.35	0.17	0.18	0.06	0.08
CD (P=0.05)	1.06	0.75	1.57	1.37	0.68	0.70	0.22	0.30
Weed management practices(w)								
Oxy *fb Clod*	1.45(2.78)b	1.61(3.81)b	3.25(18.33)b	3.13(16.74)b	1.49(3.89)b	1.61(4.99)b	2.78(11.11)a	3.45(18.04)a
Bis-Na	2.19(6.67)a	1.78(4.34)b	3.19(15.00)b	3.22(15.34)b	2.46(9.44)b	2.55(10.25)b	2.44(9.44)b	2.83(13.54)b
IP*fb* 1-HW	1.27(2.22)b	1.28(2.29)c	1.07(1.67)c	0.97(0.39)c	0.99(1.11)c	1.04(1.25)c	2.40(7.78)b	2.69(10.46)b
Pendi*fb* Quiza	2.19(6.11)a	2.29(7.06)b	3.23(15.56)b	3.44(18.69)b	3.00(12.78) b	3.10(13.67)a	1.77(5.00)b	2.05(7.45)b
2-HW	0.71(0.00)b	0.71(0.00)c	0.71(0.00)c	0.71(0.00)c	0.71(0.00)c	0.71(0.00)c	0.89(0.56)c	0.78(0.16)c
WC	2.89(10.56)a	3.46(15.73)a	5.28(39.44)a	5.41(40.93)a	4.15(22.78) a	4.08(21.91)a	3.95(20.56)a	4.85(31.83)a
SEm±	0.28	0.32	0.54	0.56	0.36	0.42	0.41	0.50
CD (P=0.05)	0.81	0.94	1.55	1.62	1.05	1.20	1.19	1.45
S*W	S	S	S	S	S	S	S	S

Data are subjected to square root transformation, original (non-transformed) values given in parenthesis. Oxy *fb Clod* = Oxyflourfen 0.1kg a.i/ha *fb*clodinafop 60a.i/ha (PoE), Bis-Na =Bispyribac-Na 20 g a.i/ha (PoE) (15DAS),IP*fb* 1-HW = Isoproturon 0.75 kg a.i/ha (PE) *fb*1-Hand Weeding (30 DAS), Pendi*fb*Quiza = Pendimethalin 1.0 kg a.i/ha *fb* Q uizalofop-ethyl 0.04 kg/ha (PoE), 2-HW =2-HW (20 & 40 DAS),WC = Weedy check.

Table.3 Biometrical observation of guava and bael plantation

Guava field plantation								
	Plant Height (m)		Canopy diameter (m)		Crown length (m)		Girth (m)	
	At time of sowing of finger millet[a]	At harvest of finger millet[b]	At time of sowing of finger millet[a]	At harvest of finger millet[b]	At time of sowing of finger millet[a]	At harvest of finger millet[b]	At time of sowing of finger millet[a]	At harvest of finger millet[b]
Mean	4.31	4.48	4.78	4.95	3.86	3.97	0.35	0.36
Range	3.68 – 4.87	3.75– 4.95	4.26 – 5.48	4.96 – 6.09	3.35 – 5.54	3.48 – 4.39	0.35 – 0.37	0.35– 0.38
SD	0.32	0.34	0.38	0.39	0.28	0.29	0.086	0.086
Bael field plantation								
Mean	6.61	6.82	7.50	7.72	5.55	5.67	0.55	0.56
Range	6.09 – 7.01	6.24– 7.50	6.78 – 5.58	7.0 – 8.05	4.87 – 6.01	5.02 – 6.24	0.55 – 0.59	0.57 – 0.61
SD	0.21	0.25	0.33	0.36	0.37	0.37	0.03	0.03

a: Observation recorded on 12.09.2018, b: Observation recorded on 12.11.2018.

Fourthly, as per Burman *et al.,* (2009)and Anusha *et al.,* (2015) sole crop grown under open field condition not only have less competition for light but also for the moisture, as compared to intercrops in association with different tree spacing. This might be one of the prime reasons for reduced yield under agro-forestry system.

Previous study conducted by Rahangdale *et al.,* (2014) also recorded higher growth and yield attributing characters of different crops like, mungbean, soybean, paddy and till in the open condition as compared to bamboo based agrisilviculture system. These results are in conformity with the findings of Handa *et al.,* (1995), Bihari (2001), Shanmughavel and Francis (2001) and Ahlawat *et al.,* (2008). Previous experiment conducted in *kharif* season under similar location also showed the higher crop growth and yield attributes of cowpea in open-field condition as compare to guava and custard apple-agri-horti system (Kumar, 2019). Secondly, guava plantation releases certain allelochemicals in root rhizosphere which are responsible for selective inhibition of weed flora under guava plantations (Kawawa *et al.,* 2016, Chapla and Campos 2010 and Thapaliyal *et al.,* 2008).

Furthermore, after the open-field condition, the highest growth, yield attributes and yield of finger millet was observed under guava agri-horti system over bael agri-horti system. Actually, in bael agri-horti system due to higher canopy diameter and crown length there was more shading effect on the finger millet, thus the performance of the crop was adversely affected (Elizabeth *et al.,* 1990).

On the basis of the investigation, it can now be concluded that under eastern Uttar Pradesh, finger millet under guava based agri-horti system showed highest gross return and net return of combined economics (finger millet+fruit) as well as followed by bael based agri-horti system and open field. However, open field condition recorded the highest profit (B:C ratio) among the agro-forestry treatment tested. Moreover, bael based agrohorti system effectively suppressed the weeds, particularly critical period of crop-weed competition and enhance the yield of finger millet followed by guava based agri-horti system and open field.

Application of 2-HW (20 & 40 DAS) and isoproturon 0.75 kg/ha (PE) *bf* 1- HW (30 DAS) (W_3) effectively manage the weeds vis-à-vis produced higher crop growth, yield attributes and yield of finger millet. Although, 2-handweeding (45 & 60 DAS) have the higher weed suppression (WCE 92.91), crop growth and yield (3786.01kg/ha) of finger millet, however, under labours scarcity, application of isoproturon 0.75 kg/ha (PE) *bf* 1- HW (30 DAS)also gave comparable weed smothering (WCE 80.56) and enhanced yield attributes and yield (3522.02 kg/ha) of finger millet.

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