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Productivity and Economics of Intercropping of Finger Millet (*Eleusine coracana*) and Amaranth (*Amaranthus* spp.) in Rainfed Hills of Uttarakhand

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ABSTRACT

A field experiment on finger millet (*Eleusine coracana* (L.) Gaertn.) and amaranth (*Amaranth* spp.) intercropping was carried out for two consecutive years during *kharif* season of 2016 and 2017 at College of Forestry, Ranichauri, Tehri Garhwal, Uttarakhand, India to identify the most promising intercropping systems for improving productivity of cropping system followed in rainfed hills of Uttarakhand. Seven treatments consist of T_1: Sole finger millet, T_2: Sole Amaranth, T_3: Finger millet+Amaranth (4:1) T_4: Finger millet+Amaranth (90:10), T_5: Finger millet+Amaranth (85:15), T_6: Finger millet+Amaranth (80:20), T_7: Farmer's practice of Finger millet+Amaranth (60:40) was laid out in a randomized block design with three replications. Finger millet + Amaranth (90:10) i.e., T_4, produced 58.8% higher finger millet grain equivalent yield (FMEY) over farmer's practice (T_7) of finger millet and amaranth (60:40) and 27.7% higher than the sole amaranth (T_2). The significantly higher finger millet straw equivalent yield was recorded in sole FM (T_1) than farmers practice (T_7) and was statistically on par with finger millet+amaranth (4:1) (T_3) and finger millet+amaranth (90:10) (T_4) However, highest land equivalent ratio (1.12), net returns (₹ 31366 ha^{-1}) and benefit cost: ratios (2.30) were also recorded with (T_4) finger millet+ amaranth (90:10 ratio). The lowest benefit cost ratio (1.12) was registered in (T_7) farmer's practice. Therefore line sowing of finger millet+amaranth (90:10 ratios) would be more beneficial than the mixed cropping in rainfed hills of Uttarakhand.

KEYWORDS: Intercropping, finger millet, *Eleusine coracana*, amaranth, mixed cropping

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

Uttarakhand has 0.8 million hectares of cultivated area constituting 16% of total geographical area, out of which 90% is hilly and 10% is plain area (Maikhuri et al., 2009). Most of the resource-poor farmers produce cereals for their subsistence in 80% of the arable land (Sati and Wei, 2018). Finger millet (*Eleusine coracana* (L.) Gaertn), locally known as *ragi or mandua,* is the most dominant *kharif* season crop in rainfed hills of Uttarakhand whereas rice is dominated in irrigated area. Finger millet has importance in hill agriculture as it is able to grow in low fertile soil and efficiently withstand under low soil moisture conditions in rainfed area. Finger millet is having health benefits such as anti-diabetic, anti-diarrheal, anti-ulcer, anti-inflammatory, anti-tumerogenic, atherosclerogenic , anti-microbial and antioxidant properties along with high nutrient content such as calcium (0.34%), dietary fiber (18%), phytates (0.48%), protein (6%–13%), minerals (2.5%–3.5%) and phenolics (0.3%–3%) (Saleh et al., 2013, Palanisamy et al., 2014, Chethan and Malleshi, 2007, Chandra et al., 2016). The finger millet grain and forage are important source of livestock feed (Verma and Patel, 2013, Wafula et al., 2017). Finger millet occupies 94 thousand hectares of area and produces 114 thousand metric tons with the productivity level of 1218 kg ha^{-1} during 2018-19 in Uttarakhand (Anonymous, 2018–19). Amaranth is locally known as *marshu* or *chua* in Uttarakhand. Amaranth is rich in macronutrients, micronutrients, vitamins, minerals and essential amino acids, particularly high quality lysine (Coelho et al., 2018). Amaranth occupies 5678 hectares of area and produces 5903 metric tons with productivity level of 1040 kg ha^{-1} in Uttarakhand (Anonymous, 2018–19). Amaranth is rich in nutrients such as protein 14–19%, carbohydrates 62–66%, fiber 4–5%, fat 6–7%, ash 2.5–4.4% (Mlakar et al., 2009, Iftikar and Khan, 2019, Ribeiro et al., 2018). Amaranth is being cultivated predominantly in hilly region of Garhwal of Uttarakhand. Both the crops are sown under dry condition before the onset of monsoon, therefore, occurrence of drought at the time of germination and critical crop-growth stages severely affect its productivity (Bantie et al., 2014, Maitra, 2020). The farmers of this region generally grow finger millet and amaranth as mixed cropping through broadcasting mixed seed of both the crops. Besides having advantage of resource use efficiency and yield stability by mixed cropping, weed management and competition challenges are also associated with mixed cropping (Lizarazo et al., 2020). The mixed cropping of finger millet and amaranth are not able to realize the yield potential in absence of flexible adjustment of crop mixture. Intercropping is the main device to adjust crop mixture and increase diversity that provides insurance against risks and aberrant rainfall behavior in rainfed environments (Dutta and Bandyopadhyay, 2006). Intercropping is known to produce stable yields from diversified crops with minimum use of inputs with respect to nutrient supply and plant protection, focusing on sufficient food under healthy environmental conditions (Zhang et al., 200, Franco et al., 2015, Maitra et al., 2020, Manasa et al., 2018, Kiwia et al., 2019, Opole, 2019). Intercropping is being considered to utilize the resources in effective and economical way to increase production per unit area and per unit time(Gebru, 2015). Land holdings in Uttarakhand hills are fragmented where intercropping can be practiced easily. In view of the paucity of the information on intercropping system of finger millet and amaranth, the current experiment was designed to provide a better inter cropping system of finger millet and amaranth to stabilize the productivity of rainfed hills of Uttarakhand.

2. MATERIALS AND METHODS

On-farm experiment was carried out for two consecutive years during *kharif* season of 2016 to 2017 at Research and extension center Gaja, College of Forestry, VCSG Uttarakhand University of Horticulture and Forestry, Ranichauri, Tehri Garhwal, Uttarakhand, India.The site of the experiment was lying between 30°15 N latitude and 78°30 E longitudes with elevation of 1750 m above mean sea level under mid hill zones of Uttarakhand. The soil of the experimental site is silty clay loam with medium depth having acidic pH (5.7), 0.73% organic carbon, 216 kg ha^{-1} available N, 14.16 kg ha^{-1} available P and 412 kg ha^{-1} available K. Total rainfall received during crop period was 844.9 and 1186.9 mmduring 2016 and 2017, respectively. Seven treatments were designed for study in a randomized complete block design with three replicates each. Theseseven treatments consist of T_1:Sole finger millet, T_2: Sole Amaranth, T_3: Finger millet+Amaranth (4:1), T_4: Mix-cropping of finger millet+Amaranth (90:10), T_5: Mix-cropping of finger millet+Amaranth (85:15), T_6: mix-cropping of finger millet+Amaranth (80:20),T_7: Farmers' practice (mixed cropping of Finger millet+Amaranth (60:40). T_3 treatment was executed by sowing finger millet and amaranth in separate rows and in definite row ratios. Treatment T_4, T_5 and T_6 were sown in line by mixing of seeds in respective proportion of seed rate of selected crops. In case of T_7 treatment seeds of both the crops were mixed in respective proportion of seed rate and sown through broadcasting. The experiment was conducted in the first fortnight of June every year. A fertilizer dose of 40-20-20 kg of N:P:K ha^{-1} was applied to finger millet and finger millet-based mixed/ intercropping. Indices for assessment of yield advantages like finger millet equivalent yield (FMEY), land equivalent ratio (LER) were computed using standard expressions. The

economics of the treatments were worked out on the basis of prevailing market prices of inputs and outputs.The data were analysed by using proc (glm) of SAS and OPSTAT of COBS&H CCS HAU, Hisar.

3. RESULTS AND DISCUSSION

Grain yield of finger millet in intercropping was recorded lower than the sole crop due to less plant population of finger millet (Table 1). Similar results were reported by Dass and Sudhishri, 2010 and Nigade et al. (2012). The reduction in finger millet yield was more in farmers practice due to high plant population of intercrop amaranth and lower population of finger millet than the sole finger millet treatment. The increase in the yield of finger millet in intercropping was recorded with the reduction of intercrop (Amaranth) plant population. Lower finger millet and amaranth yield was recorded in farmer's practice, *i.e.*, broadcasting of finger millet+amaranth(60:40), due to higher plant population and crowding and shading effect of intercrop on finger millet.

Among the inter-cropping and mixed cropping treatments, mixed-cropping system of T_4: Finger millet+amaranth (90:10) recorded higher yields of finger millet and amaranth (Table 1). The grain yield of finger millet was higher in 2017 than 2016 due to favourable weather conditions. While the grain yield of amaranth was recorded less in 2017 than 2016 due to infestation of leaf webber. Finger millet and amaranth straw yields were higher in the sole crop than the intercrop. Among the treatments, maximum straw yield of finger millet was recorded in T_5: finger millet+grain amaranth (85:15) in 2016 and in T_4: finger millet+amaranth (90:10) in 2017 while straw yield of amaranth was obtained highest in T_4: finger millet+grain amaranth (90:10) during both the years.

Table 1: Grain and straw yield of finger millet and amaranth under different intercropping system

Treatment No.	Treatment details	Grain yield (kg ha^{-1})				Straw yield (kg ha^{-1})				Finger millet grain equivalent yield (kg ha^{-1})			Finger millet straw equivalent yield (kg ha^{-1})		
		2016		2017		2016		2017							
		FM	AM	FM	AM	FM	AM	FM	AM	2016	2017	Mean	2016	1017	Mean
T_1	Sole FM	1613	0	1877	0	4400	0	3949	0	1613	1877	1745^{ab*}	4400	3949	4175^{b}
T_2	Sole AM	0	1267	0	1039	0	4600	0	2709	1584	1299	1442^{acd}	3450	3387	3418^{ab}
T_3	FM+AM (4:1)	1153	400	1485	123	3333	1467	2467	592	1653	1639	1646^{abd}	4433	3207	3820^{b}
T_4	FM+AM (90:10)	1087	500	1672	240	3400	1833	2587	648	1712	1972	1842^{b}	4775	3397	4086^{b}
T_5	FM+AM (85:15)	1080	340	1144	121	3467	1500	2032	536	1505	1295	1400^{cd}	4595	2702	3649^{ab}
T_6	FM+AM (80:20)	1080	327	963	104	3400	1400	1811	523	1488	1093	1290^{c}	4450	2464	3457^{ab}
T_7	FM+AM (60:40)	1007	313	784	110	3100	1300	1237	349	1398	921	1160^{c}	4075	1674	2875^{a}
	SEm±									98	80	67	222	234	158
	CD (p=0.05)									NS	248	208	685	720	487

*a,b,c,and d are used to indicate similar group on the basis of tukey's grouping

Finger millet grain equivalent yield was recorded highest in T_4: Finger millet+amaranth (90:10) and minimum was recorded in T_7: Farmer's practiceof finger millet+amaranth (60:40) during both the years (Table 1). As per tukey's grouping (Figure 1), the finger millet grain equivalent yield in T_4: finger millet+amaranth (90:10) was on par with sole finger millet and T_3: Finger millet+amaranth (4:1) while equivalent straw yield in all treatments were significantly higher than the T_7: farmer's practice i.e. mixed cropping of finger millet and amaranth (60:40). The higher finger millet grain equivalent yield in T_4: finger millet+amaranth (90:10) was due to an appropriate plant population of amaranth with finger millet and less competition between the crops. The T_4: Finger millet+amaranth (90:10) recorded 5.56% and 27.7% higher mean grain equivalent yield than the T_1: sole finger millet and T_2: Sole amaranth, respectively. When compared with the T_7: Farmer's practice of mixed cropping of finger millet and

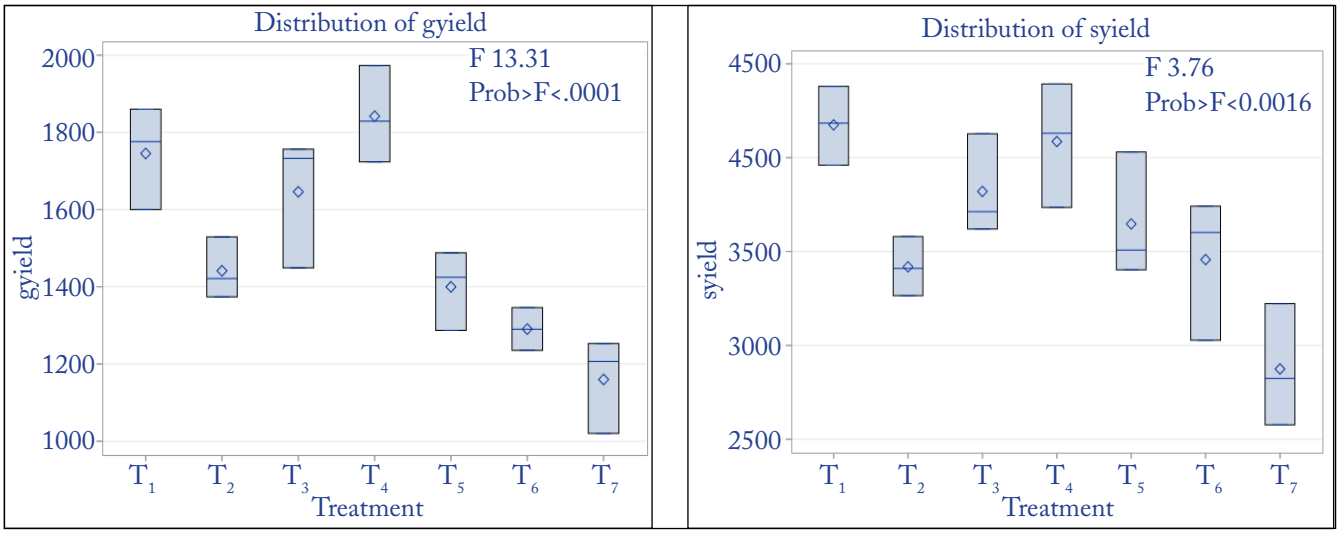

Figure 1: Finger millet grain and straw equivalent yield under different intercropping system

amaranth (60:40), T_4: Finger millet+amaranth (90:10) recorded 58.8% higher mean finger millet grain equivalent yield. Jakhar et al. (2015) also reported higher finger millet grain equivalent yield under strip cropping system of finger millet+groundnut (6:4). Severe competition exerted by amaranth on finger millet under farmer's practice (T_7) might lead to reduce the mean finger millet grain equivalent yield. The two year mean of finger millet equivalent straw yield was recorded significantly higher in T_1: sole finger millet which is statistically at par with T_4: Finger millet+amaranth (90:10) and T_3: Finger millet and amaranth (4:1) than the T_7: Farmer's practices, *i.e.*, mixed cropping of finger millet+amaranth (60:40). The two years mean of finger millet straw equivalent yield of T_4: Finger millet+amaranth (90:10) was 42.12% higher than the T_7: farmer's practices.

The two year mean of combined land equivalent ratio was also recorded highest (1.10) in T_4: finger millet+amaranth (90:10) (Table 2). Yadav (2018) also reported higher land equivalent ratio under the intercropping system of finger millet and green gram or pigeon pea. Minimum land equivalent ratio was recorded in case of T_7: Farmer's practices (0.87 in 2016 and 0.52 in 2017). Data revealed that land equivalent ratio was decreased when finger millet population decreased and amaranth population increased. Land equivalent ratio in T_4: finger millet and amaranth (90:10) was recorded higher due to higher equivalent grain yield of finger millet and amaranth and higher sale price of amaranth than the finger millet.

The maximum net return (₹ 45011 ha^{-1}) was recorded in T_4: finger millet+amaranth (90:10) and lowest net return (₹ 28942 ha^{-1}) was recorded in case of T_7: Farmers practice of mixed cropping of finger millet and amaranth (60:40) (Table 3). It was only because of higher grain and straw yields of the finger millet and amaranth than other treatments. Manjunath and Salakinkop (2017) and Manjunath et al. (2018) reported higher net return in finger millet, little millet and proso millet based intercropping

Table 2: Land equivalent ratio under different finger millet and amaranth intercropping

Treatment No.	Treatment details	LER						
		2016			2017			Mean of two year
		LER of Finger Millet	LER of Amaranth	Combined	LER of finger millet	LER of Amaranth	Combined	
T_1	Sole FM	1	0	1	1	0	1	1.0
T_2	Sole AM		1	1		1	1	1.0
T_3	FM+AM(4:1)	0.71	0.32	1.03	0.79	0.12	0.91	1.0
T_4	FM+AM(90:10)	0.67	0.39	1.07	0.89	0.23	1.12	1.1
T_5	FM+AM(85:15)	0.67	0.27	0.94	0.61	0.12	0.73	0.8
T_6	FM+AM(80:20)	0.67	0.26	0.93	0.51	0.1	0.61	0.8
T_7	FM+AM(60:40)	0.62	0.25	0.87	0.42	0.11	0.52	0.7

Table 3: Economics of different finger millet and amaranth intercropping

Treatment No.	Treatment details	Mean FM grain equivalent yield (kg ha^{-1})	Mean FM straw equivalent yield (kg ha^{-1})	COC (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C Ratio
T_1	Sole FM	1745	4175	13606	43252.67	29647	2.18
T_2	Sole AM	1442	3418	13546	35670	22124	1.63
T_3	FM+AM(4:1)	1646	3820	13986	40556.33	26570	1.90
T_4	FM+AM(90:10)	1842	4086	13646	45011.67	31366	2.30
T_5	FM+AM(85:15)	1400	3649	13646	35293.67	21648	1.59
T_6	FM+AM(80:20)	1290	3457	13646	32720.67	19075	1.40
T_7	FM+AM(60:40)	1160	2875	13646	28942.33	15296	1.12

system, respectively than the sole crop. The benefit-cost ratio was also higher (2.30) in T_4: Finger millet+amaranth (90:10) followed by T_1: sole finger millet (2.18) and T_2: sole amaranth (1.63). The lowest benefit cost ratio (1.12) was registered in T_7: Farmers practice, i.e., mixed cropping of finger millet and amaranth.

4. CONCLUSION

The intercropping of amaranth in finger millet by mixing seeds of finger millet and amaranth in the seed rate ratio 90:10 and sown in lines would be beneficial to the farming community than the mixed cropping of farmer's practice of finger millet and amaranth (60:40) under rainfed hills of Uttarakhand.

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