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Ginger (*Zingiber officinale*) based intercropping systems for enhancing productivity and income – a farmers' participatory approach

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ABSTRACT

Ginger (*Zingiber officinale* Rosc.), an important medicinal and aromatic rhizomatous spice crop has potential for improving the livelihood of hill farmers. A participatory field study was conducted in 35 farmers' field of Mawthei village (25°44'18.57" N, 91°58'27.89" E and elevation of 1000-1200 m amsl) of Meghalaya to identify a sustainable ginger based intercropping system to improve income of the resource poor hill farmers. Results indicated that fresh rhizome weight was the highest in ginger as sole crop (208 g/plant) which was at par with ginger + soybean, ginger + maize + French bean and ginger + groundnut intercropping systems. Ginger + maize + French bean + pumpkin system recorded the highest Ginger Equivalent Yield (GEY, 9.24 t/ha), i.e. 15.20% higher than sole ginger crop yield. Maximum Land Equivalent Ratio (LER) was obtained in ginger + maize + French bean (2.63) followed by ginger + maize + French bean + pumpkin (2.57) system. The highest net returns were recorded with ginger + maize + French bean + pumpkin (₹ 3.36 lakh/ha) followed by ginger + maize + French bean (₹ 3.17 lakh/ha) systems. The intercropping of ginger + groundnut recorded highest benefit cost ratio (3.42), followed by ginger + pumpkin and ginger + maize + French bean. Thus, adoption of ginger + maize + French bean + pumpkin and ginger + maize + French bean intercropping systems may help in improving the economic conditions of the hill farmers in eastern Himalayas.

Keywords: Eastern Himalayan region, Ginger based intercropping, Land Equivalent Ratio, Net returns**,** Relative yield

Ginger (*Zingiber officinale* Rosc.) is an important commercial crop grown for its aromatic rhizomes, which is used both as a spice and a medicine. In India, during 2018, ginger was cultivated in an area of 0.16 million ha with production 1.412 million tonnes contributing 32.75% of the global production. The major ginger producing states of India are Gujarat, Rajasthan, Andhra Pradesh, Karnataka and the North Eastern Region (NER) (Spices Board 2016). In NER, ginger is mainly cultivated in Assam (28.31%), Sikkim (18.53%), Meghalaya (14.97%) and Arunachal Pradesh (11.52%) (NHB 2018). The ginger rhizomes produced in NER are reported to have higher oil (1.6-2.5% to that of 1.5-2.0%) and oleoresin content (5.9-8.5% to that of 5.0-8.0%) than that produced in other parts of India (Rahman *et al.* 2009). Traditionally, ginger is cultivated in *jhum* system or shifting cultivation involving slashing and burning and land rotation. Intercropping in ginger is not uncommon however, in an irregular pattern and farmers generally do not supplement any nutrients to the soil. Being a nutrient exhaustive crop, application of manure and fertilizer is reported to improve the productivity of ginger crop substantially (Yanthan *et al.* 2010). Off late, a high incidence of diseases and insect-pest has been reported in ginger attributing to low production (Rymbai *et al.* 2018). In hilly areas, leguminous crops such as soybean (*Glycine max* L.), groundnut (*Arachis hypogaea* L.) and French bean (*Phaseolus vulgaris* L.) are the main intercrops in any cropping system and are known to play a vital role in food security, income generation, and sustaining environment. While, maize (*Zea mays* L), pumpkin (*Cucurbita pepo* L.), cucumber (*Cucumis sativus* L.), chilli (*Capsicum annuum* L.) and colocacia (*Colocasia esculenta* L.) has also been incorporated as intercrop in ginger cultivation as common practice; however, the productivity and potential economic returns of each intercropping system are not objectively studied through on-farm research. Further, there is a need to identify efficient cropping system for conserving natural resources and sustain productivity. Therefore, the present study was undertaken to find out the suitable intercropping combination for increasing total productivity, sustainability and economic returns of the farmers through participatory mode.

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MATERIALS AND METHODS

The study was carried out during 2015–17 in 35 farmers' field of Mawthei village in Ri-Bhoi district of Meghalaya located at an altitude of 25°44'18.57" N and 91°58'27.89"E and the elevation of 1000-1200 m amsl. The soil type in the study site was sandy loam in nature with low *p*H (4.4) and average soil fertility status of the fields (0-20 cm) was low in available N (140.1 kg/ha), P (5.16 kg/ha), and medium in available K (186.21 kg/ha) and soil microbial biomass carbon (SMBC) (163.02 µg/g). The total average annual rainfall recorded during the period in the area was 2202.4 mm. The treatments comprised of ginger as sole crop (control), ginger + maize, ginger + pumpkin; ginger + cucumber, ginger + soybean, ginger + chilli, ginger + colocacia, ginger + groundnut, ginger + maize + French bean, ginger + maize + pumpkin and ginger + maize + French bean + pumpkin intercropping systems. The experiment was conducted in a randomized block design with three replications. Ginger spacing was maintained at 40 × 30 cm in a bed of 1 m width, 10 m length and height of 0.15 m for both sole cropping and intercropping systems. Maize was sown in between rows of ginger at a spacing of 30 cm, chilies at spacing of 60 cm, soybean at a spacing of 10 cm, colocasia at spacing of 45 cm and groundnut at a spacing of 10 cm between plants. French bean was sown in the same hill with maize in between rows of ginger, while pumpkin and cucumber were sown at 2.5 m between plants along the outer rows of the beds. The standard cultural practices were followed throughout the experiments. Farmyard manure (10 t/ha), N (120 kg/ha), P_2O_5 (80 kg/ha), K_2O (90 kg/ha) and lime (300 kg/ha) were applied in furrow uniformly prior to planting in all the treatments. All the crops were grown as a rainfed crop and weeds were controlled manually.

The relative yield of each crop and relative yield totals (RYT) of the component crops were determined according to Schultz *et al.* (1982) as; RYT = P1/M1 + P2/M2, where P1 and P2 are the yields of two intercrops and M1 and M2 are the yields of each crop in a monoculture system.

The Ginger Equivalent Yield (GEY) was calculated by using the following formula.

$$\text{GEY} = \text{Ginger yield (t/ha)} + \frac{\text{Yield of intercrop} \times \text{Price of intercrop}}{\text{Price of ginger}}$$

The land equivalent ratio (LER) was also computed as LA+LB = AI/AS+BI/BS, where LA and LB are the respective LERs of two crops A and B, LA is obtained by dividing the yield of crop A in intercropping (AI) by the yield of the same crop in sole cropping (AS). LB is calculated in the same way (Vandermeer 1989).

The net income per ha was calculated by deducting the total cost of cultivation from gross return per ha. The benefit cost ratio was obtained by dividing the Gross returns by Cost of cultivation.

RESULTS AND DISCUSSION

Growth and yield attributes of ginger: Results indicated significant effect of different intercropping systems on growth and yield attributes of ginger (Table 1). Plant height of ginger was recorded maximum in sole crop (83.3 cm) followed by ginger + soybean (80.7 cm) system. Similarly, number of leaves were the highest in sole crop (87.0) followed by ginger + soybean (85.0). Fresh rhizome weight per plant was the highest in ginger as sole crop (207.7 g) which was at par with that of ginger + soybean (204.1 g) and ginger + maize + French bean (203.4 g) and ginger + groundnut (203.0 g) intercropping systems. Intercropping of ginger with soybean, groundnut and French bean did not affect yield of ginger significantly (Fig 1). Results revealed that the highest yield of ginger was obtained as sole crop (16.7 t/ha), followed by ginger + soybean (16.4 t/ha) system (Fig 1). It was observed that yield of ginger was affected by different intercropping systems excepting soybean, groundnut and French bean. This may be due to competition of intercrops for limited resources with base

Table 1 Growth, yield attributes and relative yields, of different ginger based intercropping system in Eastern Himalayan region

Intercropping system	Plant height (cm)	Leaves per clump	Rhizome weight/ clump (g)	Ginger	IC1	IC2	IC3	RYT
Ginger	83.3	87.0	207.7	1				1
Ginger + maize	76.3	82.8	193.3	0.93	0.53			1.46
Ginger + pumpkin	77.3	77.3	198.3	0.95	0.15			1.11
Ginger + cucumber	77.7	80.6	202.0	0.97	0.21			1.18
Ginger + soybean	80.7	85.0	204.1	0.98	0.57			1.55
Ginger + chilli	75.3	76.3	180.2	0.87	0.51			1.38
Ginger + colocacia	68.3	73.3	173.7	0.74	0.16			0.9
Ginger + groundnut	80.4	83.7	203.0	0.97	0.67			1.63
Ginger + maize + French bean	78.3	83.0	203.4	0.97	0.36	0.57		1.9
Ginger + maize + pumpkin	73.4	75.6	184.5	0.89	0.33	0.13		1.35
Ginger + maize + French bean + pumpkin	79.8	82.6	191.8	0.92	0.34	0.15	0.51	1.93

IC1- Intercrop 1, IC2- Intercrop 2, IC 3- Intercrop 3, RYT- Relative Yield Total, NS, not significant

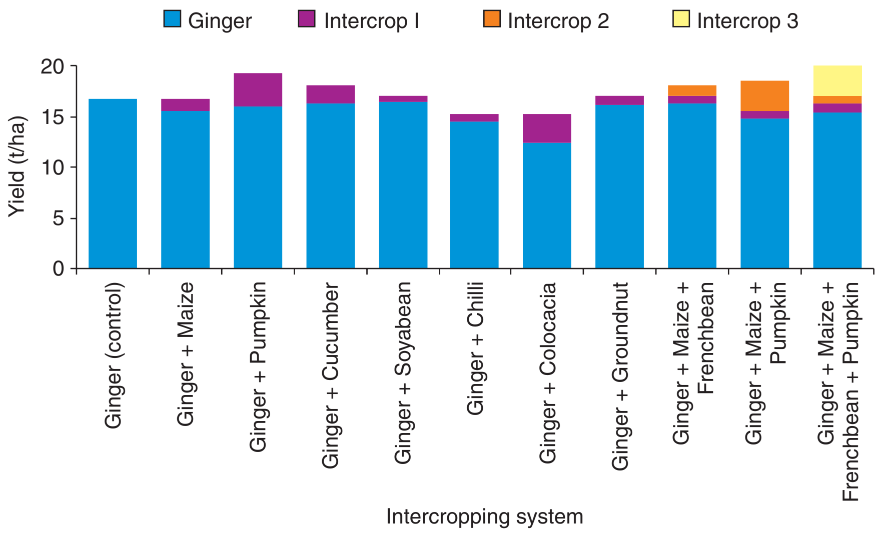

Fig 1 Yield of different ginger based intercropping systems in Eastern Himalayan region.

crop. The advantages of intercropping with legumes have been reported earlier, like intercropping of cowpea with tomato or okra (Costa and Perera 1998). Similarly, the highest GEY (₹ 105.92 t/ha), gross return (₹ 2118480/ha) and LER (2.29) of pointed gourd was reported from two rows spinach + two rows of ginger in between pointed gourd lines combination (Islam *et al.* 2015).

Relative yields under different intercropping systems: The RYT is used to evaluate the production gain when using intercropping system (Schultz *et al.* 1982). Results showed that all the ginger based cropping system had higher RYT than one exception of ginger + colocasia (0.90) (Table 1). RYT greater than one (1) indicates that the species make different demands on resources or avoid competition in some way, while values of RYT <1 imply mutual antagonism. The RYT indicated that the intercropping combinations were better than monoculture. Furthermore, RYT greater than one (over yield) often observed with intercropping systems may be attributed to suppression of weeds, pests and pathogens and enhanced the use of resources (Vandermeer 1989).

Ginger equivalent yield and land equivalent ratio: The yield of all the component crops was converted into GEY on the basis of existing market price to determine comparative efficiency of different treatment combinations. The results revealed that GEY in different intercropping system ranged from 14.06–19.24 t/ha (Table 2). The highest GEY was obtained from intercropping of ginger + maize + French bean + pumpkin (19.24 t/ha) followed by ginger + maize + French bean (18.39 t/ha) systems. All the ginger based cropping system had higher GEY than that of sole crop of ginger (16.7 t/ha) while intercropping with ginger + chilli (16.05 t/ha) and ginger + colocacia (14.06 t/ha) had lower GEY than sole crop. The GEY from intercropping was in agreement with the finding of Sanwal *et al.* (2006) where the intercropping of ginger + cowpea gave GEY of 20.49 t/ha.

Intercropping may have a positive and negative impact on the total component crop productivity (Table 2). Ginger + maize + French bean + pumpkin intercropping increased the total productivity by 15.20%. However, intercropping of ginger + colocasia (-15.78%) and ginger + chilli (-3.87%) showed total decline in productivity as compared to sole cropping. The yield of ginger was affected when grown with colocasia and chilli. Singh *et al.* (2001) reported the negative effect on production of crops when intercropped with sweet pepper. The decrease in ginger yield when intercropped with colocasia might be due to their simultaneous growing duration and similar growing habits. It has been reported that intercropping is most productive when intercrops differ greatly in growth duration and habbits so that their minimum requirements for growth resources occur at different times (Fukai and Trenbath 1993).

The productivity of the intercropping system was evaluated by the LER, which has often been considered to be an index of intercropping advantage. When the value of LER appears to be greater than one under intercropping system, this usually indicates the efficiency of this system over the sole cropping (Vandermeer 1989). The present study showed that LER as an indicator of biological efficiency in intercropping system were always greater than one (Table 2). LER of different crop combinations ranged from 0.90 to 1.97 indicating 1.70 – 15.20% yield advantage may be obtained through intercropping. The maximum LER value was obtained in intercropping of ginger + maize + French bean (1.97) followed by ginger + maize + French bean + pumpkin (1.92). Sanwal *et al.* (2006) reported that the highest LER among different intercropping system was divulged in ginger and French bean intercropped. A similar advantage of the total yield of intercrops has been reported by Natarajan (1992). The highest LER values does not reflect the highest monetary return to the farmers (Muoenke and Asiegbu 1997), however it is about the sustainability of any production system as influenced by the economic returns (Sanwal *et al.* 2006). Thus, it can be concluded that intercropping systems clearly have the potential to increase the long-term sustainability of food production and ecological sustainability through diversification.

Economics of intercropping in ginger: Intercropping increased the overall cost of cultivation of the farmers (Table 2). The cost of cultivation was ₹ 1.45 lakh/ha in case of ginger + maize + French bean + pumpkin followed by ginger + maize + French bean intercropping (₹ 1.42 lakh/ha) and the lowest was recorded in ginger + pumpkin intercropping system (₹ 1.31 lakh/ha). The highest gross return (₹ 4.89 lakh/ha) was noted in ginger + maize + French bean + pumpkin followed by ginger + maize + French bean (₹ 4.59 lakh/ha). Similarly, ginger + maize + French bean + pumpkin gave the highest net income (₹ 3.36 lakh/ha) followed by ginger + maize + French bean (₹ 3.17 lakh/

Table 2 Ginger equivalent yield, land equivalent ratio and economics of different ginger based intercropping systems in Eastern Himalayan region

Intercropping system	GEY (t/ha)	LER	Increase in total yield (%)	Cost of cultivation (₹/ha in lakh)	Gross return (₹/ha in lakh)	Net return (₹/ha in lakh)	Benefit cost ratio
Ginger	16.7			1.28	4.07	2.79	3.17
Ginger + maize	16.98	1.46	1.7	1.34	4.24	2.91	3.17
Ginger + pumpkin	17.97	1.11	7.62	1.32	4.46	3.14	3.38
Ginger + cucumber	17.34	1.13	3.83	1.33	4.33	3.00	3.26
Ginger + soybean	17.63	1.14	5.61	1.37	4.41	3.04	3.21
Ginger + chilli	16.05	1.71	-3.87	1.38	4.01	2.64	2.91
Ginger + colocasia	14.06	0.9	-15.78	1.39	3.51	2.12	2.53
Ginger + groundnut	17.64	1.59	5.66	1.32	4.52	3.20	3.42
Ginger + maize + French bean	18.39	1.97	10.16	1.42	4.59	3.18	3.23
Ginger + maize + pumpkin	17.51		4.88	1.36	4.38	3.02	3.22
Ginger + maize + French bean + pumpkin	19.24	1.92	15.2	1.45	4.80	3.36	3.33

GEY- Ginger Equivalent Yield, LER- Land Equivalent Ratio, NS, not significant

ha). Intercropping ginger + chilli and ginger + colocasia gave low returns and net income because the productivity of ginger crop is affected, the sale price of colocasia is low in the market and harvesting of chilli is very laborious.

The benefit cost ratio (BC ratio) as indicated in Table 3 ranges from 2.53 to 3.42. The intercropping of ginger + groundnut recorded highest B:C ratio (3.42), followed by ginger + pumpkin (3.38), ginger + maize + French bean + pumpkin (3.33) while the lowest was recorded in ginger + colocasia (2.53). The intercropping of ginger + maize + French bean + pumpkin and ginger + maize + French bean gave higher economic returns because in these intercropping systems the farming operation such as sowing and earthing up of maize and French bean were being done simultaneously with the base crop ginger. Maize provided staking support to French bean which has further reduced the additional cost of staking material and labour. In addition, French bean is also a nitrogen fixing crop which enhanced the productivity of this cropping system. Furthermore, addition of pumpkin crop along the *bun* (sunken bed between two raised beds) drainage and border of the field helps in prevention of flash flood – soil erosion. The study by Sanwal *et al.* (2006) have also indicated that intercropping was more productive and have positive effect on growth when planted with leguminous vegetables.

Farmer's feedback through **i**nteractions revealed that inclusion of French bean, pumpkin and maize in ginger based cropping are a favoured combination because this meet not only food, nutritional and income requirement but also help in soil conservation through effective ground covering and N-fixation. The combination also reduced the risk of farmers due to diversification as price drop in one component may be compensated with another component. Furthermore, in the event of failure of one or two component crops due to natural calamities or biotic/abiotic stresses, other components will provide some relief to farmers, thereby providing resilience against climatic aberrations.

Ginger is the main cultivated spice crop with high economic value and return in the study area. The study revealed that ginger based cropping system, viz. ginger + maize + French bean + pumpkin and ginger + maize + French bean intercropping systems performed better than other systems in term of system productivity and economic returns. To maintain the productivity and sustainability of ginger cultivation, it is therefore recommended that these combinations could be practiced; however, further studies are needed with respect to soil sustainability and pest dynamics.

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