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Land configurations and mulches influence weed suppression, productivity and economics in ginger

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ABSTRACT

Ginger is known to be sensitive to weed infestation, which severely influences crop productivity and ultimately to the economic returns. Therefore, in-situ resource conservation like land configurations namely broad bed and furrow (BBF), ridge and furrow (R&F) and flatbed (FB) and mulches with *Imperata cylendrica* (IC), pine needle (PN), double mulching of paddy straw followed by weed biomass (PS) and no mulch (NM) were assessed in ginger. Results revealed that weed density and weed dry biomass at 60 and 120 days after planting (DAP) were considerably lower with BBF followed by R&F than NM. Among mulches, the application of PN recorded lower weed density and dry biomass at 60 and 120 DAP, whereas, at second sampling, there was dramatically reduction of weed dry biomass in PS than IC. The rhizome productivity was improved with BBF (39.3-47.3%) and PS (35.8-42.2%) than FB and NM, respectively. BBF configured plots obtained 46.7-55.3% higher net returns and per day returns with 27.4-34.7% improvement in benefit to cost ratio followed by R&F than FB. Similarly, PS recorded 43.1 to 46.7% higher net returns and per day returns with 34.3 to 40.7% higher benefit to cost ratio over NM. Therefore, suitable land configurations and the use of available crop residues and tree leaf litter as mulch are promising resource conserving sustainable production technologies for ginger cultivation.

INTRODUCTION

Ginger (*Zingibar officinale* Roscoe.) is grown in tropical and subtropical regions for its spice and medicinal value. India is a leading ginger producer in the world and it has been under cultivation since antiquity. It gives a good yield and being a cash crop provides higher profit than other crops grown during the period (Choudhary *et al.* 2015). In the recent past, the area under ginger cultivation has increased owing to its assured higher productivity, demand and market availability (Kushwaha *et al.* 2013). As the crop is slow initial sprouting and growing, yield loss due to weed competition is expected to be very high,which drastically reduces the crop yield. High rainfall and warm temperature in the eastern Himalayan region (EHR) is highly conducive for year-round emergence and growth of weeds such as *Ageratum conyzoides,Cynodon dactylon, Cyperus rotundus, Digitaria* spp., *Bidens pilosa, etc*. (Sah *et al.* 2017, Choudhary and Kumar 2019) which further exaggerate the problem. Weed causes yield losses and require much of monetary investment to save the crop (Choudhary and Kumar 2013). In EHR, excessive rain during the rainy season and dry spells before and after the rainy season is another major issue for taking long-duration crops like ginger. Ginger is very sensitive to excess of water; therefore, a proper land configuration is desired for safe disposal of water and also conserve the water during dry spells (Choudhary and Kumar 2019).

In EHR, abundance of tree leaf litters and crop residues are available which are not being utilized for any commercial purpose, hence, this can be used as potential mulch materials. Mulching has a positive effect on the soil moisture, air and temperature (Bu *et al.* 2002). Favourable water regimes under mulching increase the yield, protect the soil and is economically feasible (Choudhary *et al.* 2013). The surface application of mulch favourably influences the weed flora by suppressing their emergence and subsequent growth (Lalitha *et al.* 2001, Choudhary and Kumar 2019), and may also provide the nutrients by microbial decomposition of organic mulches (Ghosh *et al.* 2006).

Despite the diverse and competitive weed flora in ginger growing areas, very little information has been generated on weed management. Use of mulches in ginger have been reported by many researchers, but limited research has so far been done to study the combined effect of land configurations and mulches on weed dynamics, productivity and economic aspect especially at warm and humid areas. Therefore, the present study aimed to examine the different land configuration and mulch options for suppressing weeds, enhancing productivity and also the economic aspect of ginger production.

MATERIALS AND METHODS

A field study was conducted during two successive years (2011-12 and 2012-13) at the research farm of ICAR Research Complex for NEH Region, Basar (27° 95' North latitude and 94° 76' East longitude, with an altitude of 631 m above mean sea level), Arunachal Pradesh, India. The climate of the region is humid sub-tropical, with the daily temperature during a year varying widely between a minimum of 4°C and a maximum of 35°C. The soil of the experimental site was silt loam in texture, with pH 5.3, organic carbon 13.1 g/kg, available nitrogen (N) 96.2 mg/kg, available phosphorus (P) 5.1 mg/kg and exchangeable potassium (K) 104.9 mg/kg. The experimental site receives annual rainfall with a high degree of variation with the range of 1800 to 2900 mm/year.

Ginger cv. '*Nadia*' (a variety with 270–300 days maturity, slender rhizome with less fibre) was planted in split plot design and replicated thrice. Main plots were assigned to land configuration *viz*. broad bed and furrow (BBF), ridge and furrow (R&F) and flatbed (FB), whereas, sub-plots were assigned to mulches *viz*. *Imperata cylendrica* (IC; 4.0 t/ha), pine needles (PN; 4.0 t/ha), double mulching of paddy straw followed by weed biomass (PS; 4.0 t/ha *fb* 2.0 t/ha respectively) and no mulch (NM). The land was prepared with one pass of mouldboard plough, harrowing and cultivator and at final land preparation, 10 t/ha of well-decomposed farm yard manure was applied. On prepared land, rhizomes at 1.5 t/ha were planted. The rhizomes were treated with mancozeb at 3 g/lit of water for 30 min and dried in shade for 4 hours and planted with a spacing of 45 × 20 cm. Urea (46% N) at 75 kg N/ha was applied in two splits [50% at 45 days after planting (DAP) and 50% at 90 DAP]. Single super phosphate (16% P_2O_5) at 50 kg P_2O_5/ha and muriate of potash (60% K_2O) at 50 kg K_2O/ha were applied in the planting row just prior to planting. The rest of the management practices were in accordance with the recommended package of practice, where one hand weeding was uniformly performed at 60 DAP after weed sampling.

The density of grasses, sedges and broad-leaved weeds were measured separately from quadrate of 0.5 × 0.5 m at three randomly selected places in each plot at 60 and 120 DAP. After counting, roots were separated from the rest of the plants and above ground parts were dried in an oven at 70±1°C for 72 hours and weighed to record weed dry biomass. The weed data was extrapolated to 1.0 × 1.0 m for further analysis and interpretation. The weed density and dry biomass data were subjected to square root transformation [$(\sqrt{x+1})$]. Weed suppression efficiency (WSE) was calculated as described below: recorded using weed dry biomass in land configured and mulched plots in comparison to flatbed and no mulch.

$$WSE\ (\%) = [(WB_{control} - WB_{treatment}) / WB_{control}] \times 100$$

where WSE, weed suppression efficiency; $WB_{control}$, weed biomass in flatbed and no mulch plot; $WB_{treatment}$, weed biomass in land configured and mulched plots

Growth parameters, *viz.* number of stalks and leaf area index of ginger were measured from five selected plants from each sub-plot at 150 DAP. Similarly, yield attributes (mother, primary and secondary rhizome) and final rhizome yield were measured from the net plot of 2.4 × 4.0 m and were extrapolated to a hectare. Economic analysis was carried out by including all the variable costs (land preparation, rhizome, manure, chemicals, labour, mulch materials) and their respective units used during the experiment. The prevalent market price of the produce was considered to calculate gross and net return and finally benefit–cost ratio was calculated.

The different parameters of the experiments were analyzed using PROC GLM procedure of the SAS Version 9.3 (SAS Institute Inc., Carry NC USA) and mean comparisons were performed based on the least significant difference (LSD) at 0.05 probability. The ANOVA results of interaction effect was indicated non-significant; hence, the data were not presented.

RESULTS AND DISCUSSION

Weed suppression

The dominant broad-leaved weed species noticed in ginger crop during experimentation were *Ageratum conyzoides* (L.), *Galinsoga parviflora* (L.), *Commelina banghalensis* (L.), *Spilanthus acmella* (auct. non L.), and *Borreria hispida* (L.) K. Schum, while *Digitaria sanguinalis* (L.) Scop, *Echinochloa colona* (L.) Link.,*Eleusine indica* (L.) Gaertner, *Cynodon dactylon* (L.) Pers. were major grasses. *Cyperus rotundus* (L.) was only sedge present. Among the treatments, there was not much variation in the type of weed species.

The weed density changed in response to BBF and recorded the lowest at 60 and 120 DAP (**Table 1**). However, in both the years (2011-12 and 2012-13), the highest weed density was recorded with FB (165.8 and 139.8/m^2 at 60 DAP, and 54.5 and 40.8/m^2 at 120 DAP). The lowest weed density was recorded with BBF (87.1 and 72.6/m^2 and 30.7 and 23.9/m^2, respectively). The R&F plots recorded the weed density between BBF and FB at both the sampling times and years. However, it was considerably more than the BBF to the tune of 20.5 and 16.6%, respectively. Correspondingly, the weed dry biomass was highest with FB (104.0 and 84.8 g/m^2, and 41.5 and 31.2 g/m^2, respectively) and lowest with BBF. The weed dry biomass was recorded 14.3 and 11.1%, respectively higher over the years in R&F followed by FB (64.5 and 56.7%, respectively) than the BBF. During the experimentation, it was noticed that weed dry biomass followed the trend of weed density at both the sampling times and years but in second year of the experiment, both the parameters were lower. Among the different land configurations followed, the highest WSE was obtained to the tune of 39.4% in both the years at 60 DAP followed by R&F (30.0 and 31.1%, respectively) over FB irrespective of mulches. This indicated that WSE significantly varied with land configurations and BBF had advantage over others. The reduction of weed dry biomasses under BBF and R&F might be due to alteration of soil surface which retarded the weed seeds to germinate. Apart from these, the fast growth and better canopy coverage under BBF facilitated to cover the ground early. This also restricted solar radiation transmission resulting in lowered germination and emergence of weeds (Ghosh *et al.* 2006, Patel *et al.* 2009).

Placement of different mulches restricted the penetration of solar radiation to soil surface leading to hampering the germination and emergence of weeds. Therefore, in PN the weed densities were 3.8 folds lower at 60 DAP, whereas, at 120 DAP it was 3.5 folds lower over FB. Whereas, over the years, the weed density in IC obtained 11.5% higher at 60 DAP and further it increased to 27.5% at 120 DAP followed by PS (40 and 30%, respectively) than the BBF. No mulch recorded the highest weed density (247 and 209/m^2, respectively during years at 60 DAP and 82.3 and 60.7/m^2, respectively during years at 120 DAP). Lowering of the weed densities under PS than NM was also evident. Similarly, weed dry biomass followed the trend of weed densities and placement of PN recorded 3.1–3.2 folds lower dry biomass at 60 DAP, whereas, it was slightly improved by 3.3–3.4 folds lower at 120 DAP over NM. At 60 DAP, the placement of IC recorded higher weed dry biomass than the PN at 60 DAP and 120 DAP. Although at 60 DAP, the weed dry biomass was more in PS during both the years (18.6-26.6%), at 120 DAP, it dramatically came down and remained higher by only 7.8-12.2% than the PN. The highest weed dry biomass was recorded in NM at both the sampling time (158.8 and 127.5 g/m^2, respectively and 65.2 and 48.7 g/m^2, respectively). The reduction of weed dry biomass at 120 DAP was relatively higher with PS than the IC (**Table 1**). This might be due to the additional application of 2 t/ha weed biomass as mulch, which suppressed the successive emergence and growth of weeds. The findings

Table 1. Weed parameters as influenced by land configuration and mulches in ginger

Treatment	Weed density (no./plant)				Weed dry biomass (g/m^2)				Weed suppression efficiency (%)			
	60 DAP		120 DAP		60 DAP		120 DAP		60 DAP		120 DAP	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Land configuration												
Broad bed and furrow	9.0(87)	8.2(73)	5.4(31)	4.8(24)	7.7(63)	7.0(52)	5.0(25)	4.5(21)	39.4	39.4	39.8	33.7
Ridges and furrow	9.9(105)	9.0(87)	5.9(36)	5.1(27)	8.3(73)	7.5(58)	5.3(29)	4.7(22)	30.0	31.1	29.6	27.9
Flatbed	12.3(166)	11.3(140)	7.1(54)	6.2(41)	9.9(104)	8.9(85)	6.2(41)	5.5(31)				
LSD (p=0.05)	0.42	0.39	0.35	0.30	0.34	0.29	0.31	0.25				
Mulches												
Imperata cylendrica	8.5(73)	7.8(60)	5.3(27)	4.7(22)	7.2(51)	6.6(43)	4.8(22)	4.4(19)	67.7	66.1	65.6	60.9
Pine needle	8.1(66.)	7.3(54)	4.8(23)	4.2(17)	7.1(50)	6.3(39)	4.5(19)	4.0(15)	68.4	67.4	70.1	69.4
Paddy straw *fb* weed biomass	9.5(91.)	8.7(76)	5.5(30)	4.8(23)	7.7(60)	7.1(50)	4.6(21)	4.2(17)	62.5	60.8	67.8	65.7
No mulch	15.6(247)	14.3(209)	9.0(82)	7.8(61)	12.5(159)	11.2(127)	8.1(65)	7.0(49)				
LSD (p=0.05)	1.71	1.59	0.99	0.83	1.15	1.03	0.71	0.59				

Figures in parentheses are original values demonstrated that weed density and weed dry biomass were significantly reduced with the application of mulches, though the extent of reduction largely depended on the type of materials used. In the same way, WSE ranged from 60.8–68.4% at 60 DAP and it was more or less similar at 120 DAP with the different mulches used. The highest WSE was obtained under PN followed by IC at 60 DAP, whereas at 120 DAP, PS was the next best to PN. Lesser weed germination and infestation by restricting the transmission of solar radiation under mulch resulted in higher WSE. Absence of application of mulch favoured the germination of weeds with considerably lower WSE was also reported earlier by Hiltbrunner *et al.* (2007) and Patel *et al.* (2009). Application of mulches reduced the weed species and provided the congenial conditions for crops to grow and develop (Moonen and Barberi 2004). The land configuration and mulches interaction did not vary significantly ($p<0.05$) with respect to weed density, weed dry biomass and WSE.

Growth parameters

Plant growth parameters *i.e.* number of stalk/plant and leaf area index (LAI) were significantly influenced by land configuration and mulching in ginger (**Table 2**). Over the years, the plants under BBF recorded with 14.6% more stalks followed by R&F (7.1%) over the FB. Similarly, LAI was 41.3% more with BBF followed by R&F (13.5%) as compared to FB. The BBF provided better opportunities to express the growth parameters, whereas, the effect of R&F was less in relation to BBF but, better than the FB. Higher LAI utilized solar radiation more efficiently for photosynthesis and could translocate to various plant parts especially to the rhizome. BBF and R&F provided the congenial conditions to plants which encouraged the plant to uptake optimum water and nutrients from root zone (Khurshid *et al.* 2006, Choudhary and Kumar 2019).

Among the mulches applied, PS recorded 44.5% more stalks followed by PN (30.3%) than the NM. Similarly, LAI was just double in PS, whereas, in PN it was more by 47.0% than the NM. The effects of PN and IC were less in relation to PS but had significantly higher than NM. This indicated that plants under PS had edge over other mulches, PS might have provided the congenial conditions for the production of more vegetative parameters. It has been reported that mulching in ginger increased early sprouting and growth in terms of height and number of shoots, mainly due to change in the physical and chemical environment of the soil resulting in increased availability of phosphorus and potassium (Maybe *et al.* 2007, Barooah *et al.* 2010).

Yield attributes and rhizome yield

Yield attributes *i.e.* mother rhizome, primary and secondary rhizome, yield/plant were significantly influenced by land configuration and mulching in ginger (**Table 2**). Plants under BBF were noticed with 29.1% more mother rhizomes, 37.8% higher primary and 22.8% superior secondary rhizomes, and 43.3% higher rhizome yield/plant than the FB. The effect of R&F was also considerably better than NM. During both the years, the BBF plots attained 39.3 and 47.3% higher rhizome yield, which was followed by R&F (30.6 and 32.3%, respectively). The lowest rhizome yield was harvested in FB (16.8 and 18.9 t/ha, respectively) (**Table 3**). The higher yields under BBF and R&F were mainly due to better growth parameters, which might have helped in the

Table 2. Growth and yield attributes as influenced by land configuration and mulches in ginger

Treatment	Growth parameter				Yield attribute							
	Stalk (no./plant)		Leaf area index at 150 DAP		Mother rhizomes (no./plant)		Primary rhizomes (no./plant)		Secondary rhizomes (no./plant)		Rhizome yield (g/plant)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Land configuration												
Broad bed and furrow	4.6	5.0	4.0	4.3	1.3	1.6	7.0	8.2	11.9	14.1	209.4	251.9
Ridges and furrow	4.3	4.7	3.2	3.5	1.2	1.4	6.0	7.0	10.9	13.0	190.9	232.7
Flatbed	4.0	4.4	2.8	3.0	1.0	1.2	5.1	5.9	9.7	11.5	146.2	175.7
LSD (p=0.05)	0.23	0.25	0.42	0.46	0.08	0.10	0.30	0.34	0.41	0.48	22.97	27.63
Mulches												
Imperata cylendrica	4.1	4.5	3.0	3.2	1.1	1.3	5.9	6.8	10.9	12.8	176.5	208.8
Pine needle	4.5	5.0	3.4	3.7	1.2	1.4	6.3	7.3	11.0	13.4	189.4	228.5
Paddy straw *fb* weed biomass	5.0	5.5	4.7	5.0	1.3	1.5	6.5	7.5	11.5	13.5	212.5	255.7
No mulch	3.5	3.8	2.3	2.5	1.1	1.3	5.4	6.5	10.0	11.6	150.3	187.4
LSD (p=0.05)	0.35	0.38	0.65	0.71	0.16	0.18	0.85	0.98	1.00	1.22	33.91	41.34

accumulation of higher photosynthates and also helped to produce more yield attributes. Similar findings were corroborated by Choudhary *et al.* (2013) in maize and Choudhary and Kumar (2019) in turmeric.

Placement of mulches recorded considerably better yield attributing characters. Application of PS resulted in 17.0% more mother rhizomes, 18.6% higher primary and 15.6% secondary rhizomes, and 38.9% higher rhizome yield/plant than the NM (**Table 2**). The effects of the application of PN and IC were also considerably better than NM, but their effects were less pertinent to the effect of PS. Better yield attributes in PS led to 42.2 and 35.8%, respectively higher rhizome yield followed by PN (27.0 and 21.0%, respectively) and IC (16.4 and 12.5%, respectively) than the NM. The lowest rhizome yield was recorded in NM (17.06 and 20.37 t/ha, respectively). Improved growth parameters with PS helped the plant to produce more photosynthates and translocation towards the sink i.e. rhizome. This accumulation of photosynthates helped the plant to develop more number of mother, primary and secondary rhizomes. Therefore, yield/plant was comparatively higher and finally led to higher rhizome yield. A similar finding was also reported earlier (Tomar *et al.* 2006). The higher rhizome yield with an application of PS was mainly due to better yield attributes (**Table 3**), and this led to the final account in formation of more rhizome yield. Rhizome yield of ginger followed the quadratic relationship with weed smothering efficiency (R^2=0.57 and 0.46, **Figure 1a** and **b**).

Economic parameters

The economic parameters i.e. net returns, benefit-cost ratio and returns/day was influenced by land configuration and mulches in ginger (**Table 3**). The economic parameters largely depend on the economic yield of crop and production cost, however, the BBF recorded the highest net returns ₹ 29.7× 10^4 in 2011-12 and it was enhanced to ₹ 36.3 × 10^4 in 2012-13, which was followed by R&F and the lowest net return obtained with FB. Similarly, benefit-cost ratio was recorded the highest with BBF (6.48 and 7.71, respectively) followed by R&F (6.19 and 7.06, respectively). The lowest benefit-cost ratio recorded with FB (**Table 3**). These were mainly due to the production of higher rhizome yield under BBF and R&F by judicious use of resources. The returns

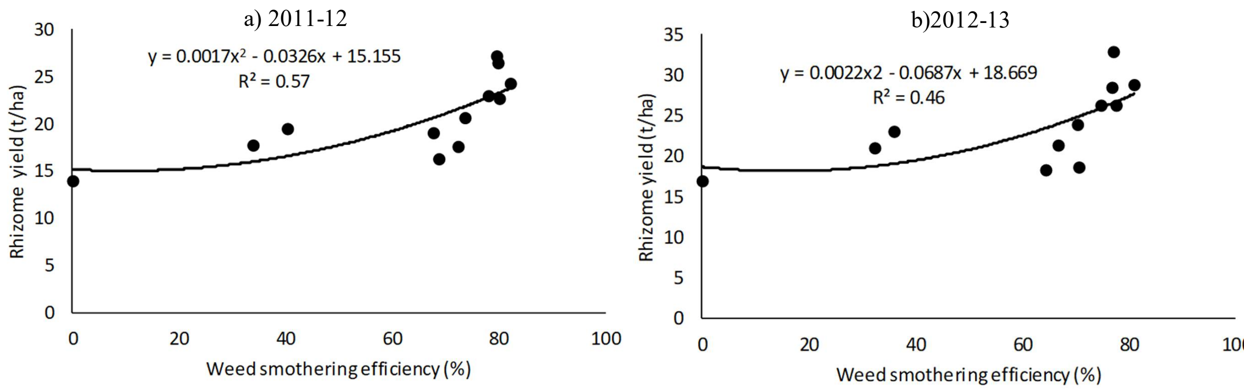

Figure 1. The relationship between rhizome yield of ginger and weed smothering efficiency as influenced by land configuration and mulches

Table 3. Rhizome yield and economic parameters as influenced by land configuration and mulches in ginger

Treatment	Rhizome yield (t/ha)		Net returns (x 10^4 ₹/ha)		Benefit: cost ratio		Returns (₹/day)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Land configuration								
Broad bed and furrow	23.40	27.83	29.68	36.33	6.48	7.71	1041.5	1274.6
Ridges and furrow	21.94	25.00	27.60	32.19	6.19	7.06	968.2	1129.4
Flatbed	16.79	18.89	20.24	23.39	5.09	5.72	710.1	820.7
LSD (p=0.05)	3.60	3.02					136.6	158.9
Mulches								
Imperata cylendrica	19.85	22.92	24.62	29.23	5.75	6.64	864.0	1025.6
Pine needle	21.67	24.66	27.39	31.88	6.33	7.20	961.0	1118.6
Paddy straw *fb* weed biomass	24.26	27.67	31.04	36.16	6.78	7.73	1089.2	1268.7
No mulch	17.06	20.37	20.30	25.27	4.82	5.75	712.2	886.5
LSD (p=0.05)	3.70	4.69	-	-	-	-	189.4	241.3

per day was also recorded highest with BBF (1041 and 1275 ₹/day, respectively) followed by R&F, whereas, the lowest return obtained with FB. Among the mulches, PS provided higher net returns (₹ 31.0 × 10^4 and 36.2 × 10^4, respectively), benefit–cost ratio (6.78 and 7.73, respectively) and return (1089 and 1269 ₹/day, respectively) followed by PN and IC, the lowest net returns, benefit-cost ratio and return/day recorded with NM. The effect of PN and IC were also considerably better than NM. However, their effect was less in relation to PS.

The results of the present study highlighted the significance of land configuration and mulches on weed suppression, productivity and economics for the production of ginger. The BBF suppressed the weeds considerably followed by R&F, whereas, application of mulches suppressed the weeds more than the FB and NM plots. The combined effects of BBF and PS were noticed with better growth and yield attributes, on account of higher rhizome yield. Economic parameters also improved with BBF and PS. BBF and R&F along with mulched plots attained with higher economic returns. In the region, mulch materials are available in plenty with no commercial use; may be potentially utilized along with suitable land configurations.

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