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VK Choudhary
ICAR Research Complex for North Eastern Hilly Region Region, Basar, Arunachal Pradesh, India

AK Vishwakarma
ICAR- Indian Institute of Soil Science Bhopal, Madhya Pradesh, India

Corresponding Author:
VK Choudhary
ICAR Research Complex for North Eastern Hilly Region Region, Basar, Arunachal Pradesh, India

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Alteration in land topography and influence of mulching on water, crop and energy productivity in ginger

VK Choudhary and AK Vishwakarma

Abstract
In-situ conservation of resources in ginger is much influenced by alteration in surface topography and placement of mulches. Ginger (*Zingibar officinale* Roscoe.) is long duration crop and sensitive to excess water and prolonged dry spells, therefore experiment was conducted during 2011-12 and 2012-13 at ICAR Research Complex for NEH Region, Arunachal Pradesh, India to know the effect of alteration in land topography and mulching on water, crop and energy productivity. Surface land topography alterations viz. broad bed furrow (BBF), ridges 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 bare land (BL) were assessed on ginger. Results revealed that both the years the runoff in BBF was reduced by 23.5%, and contributed 50.3-56.5% lower soil moisture over FB plots. Among the placed mulches, the runoff was lowered in PN by 30.3-32.0% over BL, whereas, water use efficiency was 26.5-26.7 kg/ha/mm with PS and lowest with BL plots. The rhizome yields were improved with BBF (39.3-47.3%) and PS (35.8-42.2%) than FB and BL, respectively. BBF altered plots recorded 24.6-32.1% higher harvest monetary benefit (HMB), with better energy indices, similarly, the application of PS was observed with the highest energy values. Therefore, alteration in land topography and the use of available crop residues and tree leaf litter as mulch are promising resource conserving sustainable production technologies.

Keywords: crop and water productivity, energy efficiency, ginger, land configuration, mulching

Introduction

Ginger (*Zingibar officinale* Roscoe.) is an important crop, which can be grown solitary as well as intercropped with tree species in orchards. The higher rhizome yield and assured market encourages the growers to cultivate in a larger area (Kushwaha *et al.* 2013) [12] and obtain higher profit than other field crops (Choudhary *et al.* 2015) [4]. Longer duration (270-300 days) of the crop often come across prolonged dry spells during early planting and terminal growth stage of the crop, whereas encounters flood situations during high rain periods resulting in a drastic reduction in crop yield (Choudhary and Kumar 2013) [2, 3]. The region receives an annual rainfall of 1500–4500 mm with spatial and temporal deviation, and the major volume of water receives during June-September. Ginger is planted between April-may and harvested in the month of December-January, whereas, rainfall ceases during September-October. Growing the crops like ginger is risky, without following the appropriate measures for safe disposal of excess water and conservation of soil moisture during initial planting and terminal stage of crop growth (Choudhary and Kumar 2013) [2, 3].

Alteration in land plays paramount importance and helps in the safe disposal of water, which provides an optimum condition for growth and development, formation of more rhizomes, better aeration resulting in water conservation and reduces the splash erosion (Jin *et al.* 2007) [11]. Adoption of appropriate site-specific land alteration may improve the water productivity till the harvest (Pabin *et al.* 2003; Ferrero *et al.* 2005) [15, 8], which can reduce the land preparation cost (Ortega *et al.* 2006) [14]. Apart from these, land configuration provides the opportunity of safe disposal of water, efficient utilization of rainfall, and higher crop yield (Akbar *et al.* 2010) [1]. The permanent bed offers potential advantages in improving resource use efficiency compared to a traditional flatbed with the least disturbance to soil (Singh *et al.* 2009) [18]. In the eastern Himalayan regions, plenty of crop residues weed biomass and tree leaf litters are available, which are being left no use for any commercial purpose. These materials have the potential benefit and can be utilized as mulch to reduce the soil evaporation during intense light and consistently supply the water to plants (Choudhary *et al.* 2013) [2, 3]. The placement of mulch improves infiltration, soil water retention, decreases bulk density and facilitates condensation of soil water at night due to temperature reversals (Ghosh *et al.* 2006) [9]. It also protects the splash erosion and decreases soil and nutrient erosions (Thankamani *et al.* 2016) [20].

Human energy is a primary contributor for the majority of field operations, contributes more to the energy inputs in crop production. In the region, however, the use of non-renewable resources *viz.* fossil fuels, fertilizers, pesticide application and mechanization in farming (due to steep slopes) are not common. Change in cultivation practices leads to more dependence on non-renewable energy, which significantly amends the energy use pattern (Choudhary and Kumar 2013) [2, 3]. Considering the importance of ginger in terms of wider adoption, total production and productivity, suitable management strategies need to be adopted, which could manage the soil moisture, safely dispose of the rainwater and optimum energy use would be useful to boost the ginger productivity. Keeping these in view experiment was conducted to know the effect of alteration in land topography and mulches in water, crop and energy productivity.

Materials and Methods

A field experiment was conducted at ICAR-Research Complex for NEH Region, Arunachal Pradesh Centre, Basar, India (27° 95’ North latitude and 94° 76’ East longitude, with an altitude of 631 m above mean sea level) during two consecutive years (2011-12 and 2012-13). The climate was humid subtropical, with 2400 mm annual rainfall, a minimum and maximum temperature was 4 ºC and 35 ºC, respectively. The soil of the experimental site was silt loam, acidic in reaction (pH 5.3), bulk density; 1.42 Mg/m^3, contained 1.31% organic carbon, low in available nitrogen (N, 96.2 mg/kg), available phosphorus (P, 5.1 mg/kg) and medium in exchangeable potassium (K, 104.9 mg/kg).

Ginger cv. ‘*Nadia*’ (with 270–300 days maturity, slender rhizome with less fibre) was planted in the split-plot design and replicated thrice. In main plots three alteration of land topography i.e. broad bed and furrow (BBF), ridge and furrow (R&F) and flatbed (FB), and in sub plots four mulches i.e. *Imperata cylendrica* (IC, 4 t/ha); pine needles (PN, 4 t/ha); paddy straw (PS, 4t/ha followed by weed biomass, 2 t/ha) and bare land (BL) were assigned. The smallest unit of the plot was 4.2 m × 4.8 m and between the replications, main plots and sub plots 1.0 m spacing was provided. One pass of mouldboard plough subsequently one harrowing and at final land preparation well-decomposed farm yard manure of 10 t/ha was applied finally one pass of the cultivator was used to prepare the planting bed. The treated rhizomes (mancozeb at 3 g/L of water for 30 min and shade dried for 4 h) of 1.5 t/ha were planted with a spacing of 45 cm × 20 cm. Nitrogen was supplied through urea (46%N) at 75 kg N/ha in two splits [half at 45 days after planting (DAP) and the remaining half at 90 DAP]. Phosphorus and potassium were supplied in planting rows at planting with 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, respectively. Anonymously, the crop was subjected to one manual weeding at 60 DAP.

The runoff was collected at the drainage gate of each plot. Moisture contribution from soil profile was measured to a depth of 45 cm at 15 cm increments at three random locations in each plot. The contribution of water from the soil profile was calculated as follows:

Soil water contribution (SWC, mm) = h × d × b% × 10

where SWC (mm), the contribution of water from the soil profile; h (cm), soil depth; d (g/cm^3), soil bulk density; b%, the water content in the soil. Deep percolation was not considered while study period.

Water use efficiency (WUE; kg/ha/mm) was calculated as described by Hemmat and Eskandari (2004) [10]:

Water use (mm) = Effective rainfall (mm) + soil water contribution (mm)

Water use efficiency (kg/ha/mm) = Rhizome yield (kg/ha)/water use (mm)

Harvest monetary benefit (Rs/ha/mm) = Net return (Rs/ha)/ net rainfall (mm)

Return (Rs/day) = Net return (Rs/ha)/ duration of crop (day)

Energy parameters like total input, output, energy use efficiency, specific energy and energy productivity were recorded with the standard formula (Choudhary and Kumar 2013) [2, 3].

Net energy (MJ/ha) = Energy output (MJ/ha)- energy input (MJ/ha)

Energy use efficiency = Energy output (MJ/ha)/ energy input (MJ/ha)

Specific energy (MJ/kg) = Energy input (MJ/ha)/ rhizome yield (kg/ha)

Energy productivity (kg/MJ) = Rhizome yield (kg/ha)/ energy input (MJ/ha)

The different parameters were analyzed using PROC MIXED procedure of the SAS Version 9.3 (SAS Institute Inc., Carry NC USA) and means were compared based on the least significant difference (LSD) at 0.05 probabilities. The interaction effect was not significant; hence it was not presented.

Results and discussion

Water parameters and water use efficiency

The experimental site received an average rainfall of 1488 mm in 2011-12 and 1668 mm in 2012-13. Among the alteration of land topography, the highest runoff was obtained with FB plots (645.4 and 717.3 mm, respectively), whereas, the lowest runoff was measured with BBF with a reduction of 23.5% during both the years followed by R&F (14.7 and 15.5%, respectively). The contribution of water from soil profile was lowest to the tune of 50.3-56.5% in BBF followed by 24.6-32.4% in R&F than the FB plots (Table 1). Total water use was the highest with BBF followed by R&F, whereas the least water was used in FB plots. BBF was noticed with 18.1-25.3% higher WUE, which was followed by R&F (17.5-18.3%) over the FB. The findings showed that land configuration with BBF used rainwater more efficiently and converted the available water for rhizome production. Similar findings were reported earlier in a hilly watershed in the eastern Himalaya, India (Singh *et al.* 2011) [17]. Choudhary *et al*. (2013) [2, 3] in maize also suggested that the adoption of land configuration could considerably improve the productivity and WUE than the FB and in turmeric (Choudhary and Kumar 2019) [5].

Placement of mulches materials could change the water runoff. The highest runoff was collected from BL plots followed by plots under PS. However, the lowest runoff was recorded under PN followed by IC during both the years. The runoff was 30.3-32.0% lower with PN followed by IC and PS than the BL (Table 1). The contribution of water from soil profile was 2.0 – 2.8 times higher with PN followed by IC and PS than the BL. The highest total water was used in PN plots followed by IC and the lowest with BL. The WUE recorded the highest in PS to the range of 15.8-20.5% over BL. However, the lowest WUE was recorded with IC (20.6 and 21.4 kg/ha/mm, respectively), which was 6.7-7.0% lower than the BL and PN. This had indicated that plants with PN and IC mulched plots were less efficient in converting used water to economic rhizome yield. Therefore, BL had little advantage over these mulches. PS was more efficient in converting utilized water into economic yield, thus, WUE was significantly higher over all other mulches. Higher WUE under PS might be attributed to its additional advantages of supplying plant nutrients due to early decomposition. Later, additional placement of 2 t/ha of weed biomass might have acted as double mulching also supplemented nutrients and conserved the runoff (Deng *et al.* 2006; Choudhary and Kumar 2019) [6, 5].

Table 1: Water parameters as influenced by alteration of land topography and mulches in ginger

Treatment*	Runoff (mm)		Soil water contribution (mm)		Water use (mm)		Water use efficiency (kg/ha/mm)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Alteration of land topography								
BBF	493.8	548.7	-25.8	-26.8	968.4	1092.5	24.1^a	25.5^a
R&F	550.8	606.2	-21.8	-22.2	915.4	1039.6	24.0^a	24.1^a
FB	645.4	717.3	-16.5	-17.8	826.1	932.8	20.4^b	20.3^b
LSD (p=0.05)							2.79	2.88
Mulches								
IC	503.3	573.7	-23.3	-26.8	961.4	1067.4	20.6^b	21.4^b
PN	481.8	539.3	-29.3	-31.6	976.9	1097.0	22.1^b	22.3^b
PS	559.4	609.8	-23.1	-22.4	905.5	1035.8	26.7^a	26.5^a
BL	709.0	773.4	-9.6	-8.4	769.4	886.3	22.1^b	22.9^b
LSD (p=0.05)							3.09	3.40

*Broad bed and furrow (BBF), ridge and furrow (R&F), flatbed (FB), Imperata cylendrica (IC), pine needle (PN), paddy straw followed by weed biomass (PS) and bare land (BL)

Rhizome yield

Alteration of land topography and placement of mulch influenced the rhizome yield (Table 2). The BBF plots noticed with 39.3% higher rhizome yield in 2011-12 and it was further improved to 47.3% in 2012-13, which was followed by R&F (27.0-32.3%). The lowest rhizome yield was harvested in FB (16.79 and 18.89 t/ha, respectively). The higher yields under BBF and R&F were mainly due to better growth parameters, which might have helped in the accumulation of higher photosynthates and also helped to produce more yield attributes (data not presented). Similar findings were corroborated by Choudhary *et al.* (2013) [2, 3] in maize and Choudhary *et al.* (2018) in turmeric.

Placement of PS recorded higher rhizome yield 24.26 t/ha in 2011-12 and 27.67 t/ha in 2012-13 followed by PN (21.67 and 24.66 t/ha, respectively) and IC (19.85 and 22.92 t/ha, respectively) than the BL. The application of PS might improve the growth parameters, which helped in source to sink realization resulting in higher rhizome yield (Fig 1). A similar finding was also reported earlier by Tomar *et al.* (2006) [19]. Rhizome yield of ginger followed the positive quadratic relationship with water use efficiency (R^2=0.79; Fig 2a & b).

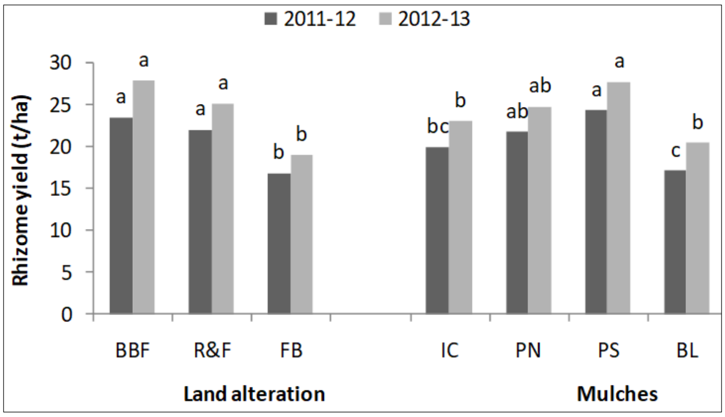


Fig 1: Effect of alteration of land topography and mulches on rhizome yield of ginger during both the year

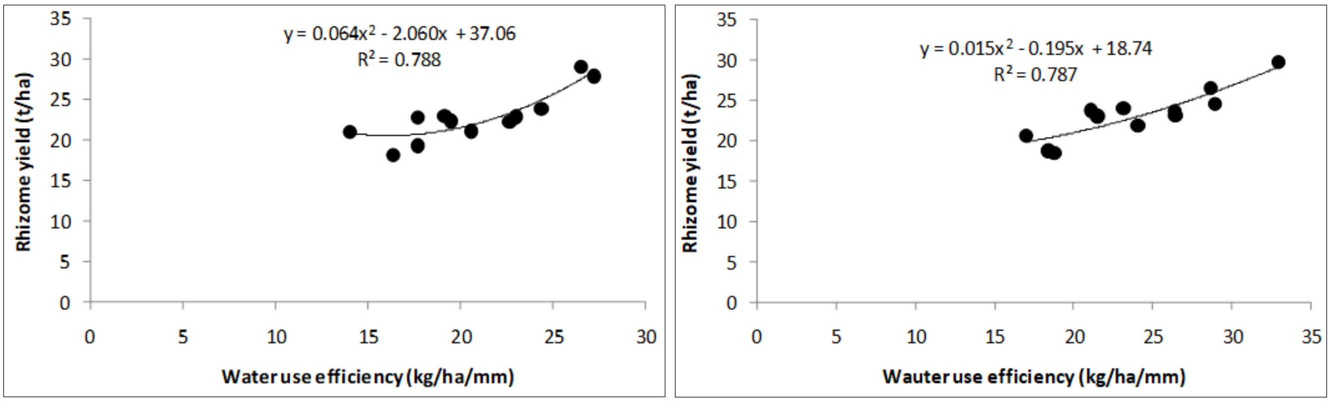
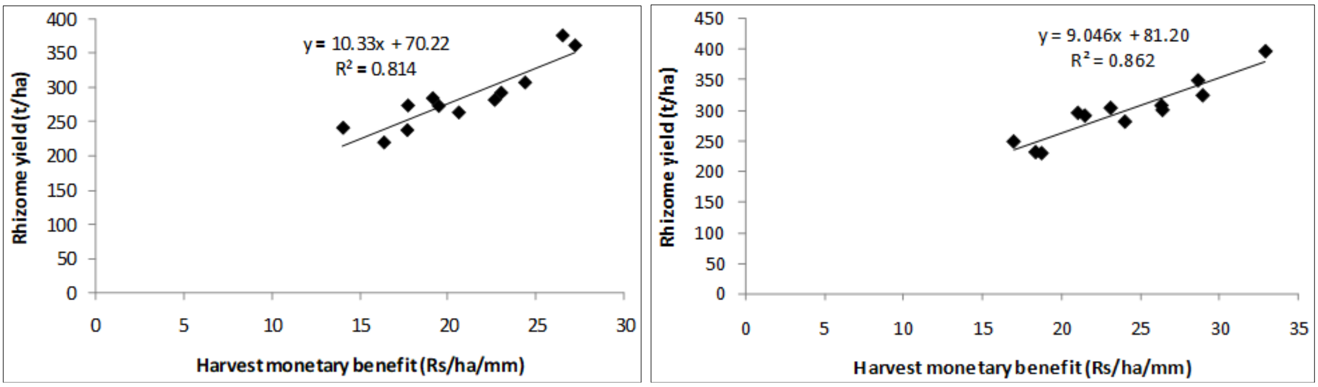


Fig 2: The relationship between rhizome yield and water use efficiency with respect to alteration of land topography and mulches in ginger a) 2011-12 and b) 2012-13

Harvest monetary benefit, per day production and returns

The harvest monetary benefit, per day production and per day returns significantly (p=0.05) influenced by alteration of land topography and placement of mulch (Table 2). The HMB was obtained highest with BBF (24.6-32.1%) which was followed by R&F (22.8-23.0%) than the FB plots. However, during second year of study, the HMB was considerably better than the first year. Similarly, per day productivity was recorded highest with BBF (39.3-47.3%) followed by R&F (30.6-32.3%) than the FB. The lowest HMB was recorded in FB (59.9 and 71.5 Rs/ha/mm during 2011-12 and 2012-13, respectively). The return per day was obtained highest with BBF to the range of 46.7-55.3% followed by R&F (36.4-37.6%) over the FB plots (712.2 and 886.5 Rs/day, respectively).

Among the mulches applied, during both the years, PS obtained higher values for HMB to the range of 22.0-29.8%, per day productivity (35.8-42.2%) and per day return (43.1-52.9%) followed by PN and the lowest with BL. The HMB was marginally lower than the BL but was statistically (p=0.05) comparable. The highest HMB under BBF along with PS was mainly due to higher yield obtained by using a unit volume of water during the crop growth period, leading to higher HMB. Similarly, per day productivities were also higher under BBF and PS due to higher per day yield. The return was mainly depended on gross return and cost involved in the production, the highest value was recorded with BBF and PS. Similar finding was reported by Choudhary *et al.* (2013) [2, 3] in maize. The crop yield, duration of crop and price of the economic produce greatly influenced the overall return and productivity of various cropping systems (Mukherjee 2010) [13], but during the study, there was no much change in the price of the ginger rhizome. HMB showed a positive linear relationship with rhizome yield during both the years (R^2=0.814 and 0.862; Fig. 3a & b).



a) b)

Fig 3: The relationship between rhizome yield and harvest monetary benefit with respect to alteration of land topography and mulches in ginger a) 2011-12 and b) 2012-13

Table 2: Harvest monetary benefit, per day production and per day returns as influenced by alteration of land topography and mulches in ginger

Treatment*	Harvest monetary benefit (Rs/ha/mm)		Per day production (Rs/ha/day)		Return (Rs/day)	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Alteration of land topography						
BBF	305.9a	331.9a	82.1a	97.6a	1041.5a	1274.6a
R&F	301.3a	309.1a	77.0a	87.7a	968.2a	1129.4a
FB	245.4b	251.3b	58.9b	66.3b	710.1b	820.7b
LSD (p=0.05)	41.84	43.02	9.12	10.60	136.56	158.93
Mulches						
IC	254.8b	272.0b	69.7bc	80.4b	864.0bc	1025.6b
PN	279.0b	288.2b	76.0ab	86.5ab	961.0ab	1118.6ab
PS	340.7a	346.1a	85.1a	97.1a	1089.2a	1268.7a
BL	262.4b	283.7b	59.9c	71.5b	712.2c	886.5b
LSD (p=0.05)	47.04	51.81	13.00	16.46	189.44	241.33

*as described in table 1

Energy parameters

The energy parameters i.e. net energy, output: input ratio, energy use efficiency, specific energy and energy productivity significantly (p=0.05) influenced by alteration of land topography and placement of mulch (Table 3). During the years, BBF noticed with the highest net energy (26.6 and 33.4 × 10^4 MJ/ha, respectively), output: input ratio (3.37 and 4.19, respectively), energy use efficiency (4.37 and 5.19, respectively) and energy productivity (0.29 and 0.34 kg/MJ) followed by R&F and the lowest values of energy parameters were recorded in FB. However, specific energy was followed the reverse trend and recorded higher values with FB (5.16 and 4.61 MJ/kg) than the others. Higher energy values in BBF and R&F were mainly due to the production of higher rhizome yield utilizing energy components (Esengun *et al.* 2007; Singh *et al.* 2007) [7, 16].

Application of PS measured the highest net energy (24.9 and 30.1 × 10^4 MJ/ha, respectively) and specific energy (5.12 and 4.51 MJ/kg) followed by PN, whereas BL recorded higher energy output: input ratio (4.83 and 5.97, respectively), energy use efficiency (5.83 and 6.97, respectively) and energy productivity (0.38 and 0.46 kg/MJ) over other placed mulches. This clearly indicates that PS efficiently converted solar energy into chemical energy which resulted in higher rhizome yield. However, the lower values for gross and net energy were obtained with BL. The higher output: input ratio, energy use efficiency and energy productivity under BL were mainly due to the production of rhizomes by using the least energy inputs.

Table 3: Energy parameters as influenced by alteration of land topography and mulches in ginger

Treatment*	Energy input (MJ/ha)	Net energy (MJ/ha)		Output: input		Energy use efficiency		Specific energy (MJ/kg)		Energy productivity (kg/MJ)	
		2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
Alteration of land topography											
BBF	89085	266585^a	333883^a	3.37^a	4.19^a	4.37^a	5.19^a	3.77^b	3.18^b	0.29^a	0.34^a
R&F	88675	244805^a	291347^a	3.09^a	3.71^a	4.09^a	4.71^a	3.98^b	3.50^b	0.27^a	0.31^a
FB	87660	167594^b	199539^b	2.21^b	2.67^b	3.21^b	3.67^b	5.16^a	4.61^a	0.21^b	0.24^b
LSD (p=0.05)		39439	45897	0.55	0.47	0.47	0.54	0.59	0.49	0.03	0.04
Mulches											
IC	94857	206925	253595	2.18^b	2.67^b	3.18^b	3.67^b	4.91^a	4.27^a	0.21^b	0.24^b
PN	94906	234443	279974	2.47^b	2.95^b	3.47^b	3.95^b	4.52^a	4.03^a	0.23^b	0.26^b
PS	119749	248981	300821	2.08^b	2.51^b	3.08^b	3.51^b	5.12^a	4.51^a	0.20^b	0.23^b
BL	44381	214963	265302	4.83^a	5.97^a	5.83^a	6.97^a	2.67^b	2.23^b	0.38^a	0.46^a
LSD (p=0.05)		NS	NS	0.83	0.68	0.68	0.83	0.81	0.78	0.04	0.05

*as described in table 1

Conclusion

It can be concluded for the two year study that in eastern Himalaya alteration of land topography to broad bed furrow or ridge and furrow will help in better disposal of water during excessive rain events and also conserve the water during dry spells. Similarly, placement of mulch paddy straw (4 t/ha) followed by weed biomass (2 t/ha) or use of pine needle as mulch will certainly increase the rhizome yield of ginger.

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