Journal of Horticultural Research 2021, vol. 29(1): 55–66
DOI: 10.2478/johr-2021-0009

ADOPTION OF GOOD AGRICULTURAL PRACTICE TO INCREASE YIELD AND PROFIT OF GINGER FARMING IN NEPAL

Rudra BARAL*[1], Bishnu Prasad KAFLE[2], Dinesh PANDAY[3], Jiban SHRESTHA[4], Doohong MIN[1]
[1]Department of Agronomy, Kansas State University, Manhattan, KS 66506, USA
[2]Nepal Agricultural Development Programme (NAMDP);
Swisscontact; Swiss Foundation for Technical Cooperation, Biratnagar, Nepal
[3]Department of Biosystems Engineering and Soil Science, University of Tennessee-Knoxville, Knoxville, TN 37996, USA
[4]Nepal Agricultural Research Council, National Plant Breeding and Genetics Research Centre, Khumaltar, Lalitpur, Nepal

Received: January 2021; Accepted: April 2021

ABSTRACT

Ginger (*Zingiber officinale*) is one of the major high-value cash crops in Nepal. Low yield, conventional farming, and limited access to production resources such as improved cultivars, production technologies, and extension services are the existing problems of Nepali ginger farmers. In this study, we conducted community based-participatory research in Ilam district, Nepal, in 2015–2017. This research aimed to explore the appropriate ginger farming technology considering yield, income, and environment. We compared the effect of four different ginger production technologies on ginger yield and net farm income that include: i) traditional practice with mother rhizome harvest, ii) traditional practice without mother rhizome harvest, iii) good agricultural practice (GAP) with mother rhizome harvest, and iv) GAP without mother rhizome harvest. The experiment was conducted in a randomized complete block design with five replications. The yield of ginger under GAP and without mother rhizome harvest was observed 17.9 $t \cdot ha^{-1}$, which was 39.8% higher than the farmers' existing practices and 45.5% higher than the national average. The cost of production was almost the same in all treatments; however, the GAP with mother rhizome-harvested treatment gave the highest benefit–cost ratio (1.5) along with the maximum net farm income (\$2072.6$\cdot ha^{-1} \cdot year^{-1}$). Thus, we suggest ginger producers adopting GAP rules to obtain a higher yield and harvesting mother rhizomes earlier for obtaining maximum profit. The GAP rules will additionally protect the environment. This study also suggests policymakers and related stakeholders promoting GAP as a sustainable production technology in agriculture-based countries like Nepal.

Key words: ginger yield, good agricultural practice, participatory approach, mother rhizome, benefit–cost analysis

INTRODUCTION

Ginger is the most widely consumed spice in Asian countries. Besides spices, it has also been used as a traditional and herbal medicine in many parts of the world particularly for the treatment of nausea, vomiting, cough, arthritis, muscle pain, and asthma (Niebyl & Goodwin 2002; White 2007; Singletary 2010; Li et al. 2019). It is one of the major high-value cash crops and high-value exportable commodities grown in the mid-hills of Nepal. According to a recent report, Nepal produced 284,000 t of ginger from 23,000 ha of land in 2018 (FAOSTAT 2020). Nepal ranks as the fourth largest ginger-producing country in the world after India, China, and Nigeria. Ginger is one of the twelfth priority export commodities of Nepal (MOC 2016). However, the mean yield of ginger in Nepal is only 12.3 $t \cdot ha^{-1}$ (MOALD 2018), which is almost 50% lower than the potential yield of 24.5 $t \cdot ha^{-1}$ (Basnet & Gurung 2018).

*Corresponding author:
e-mail: rudrabaral@ksu.edu

Conventional farming in Nepal is mostly based on traditional knowledge and low farm inputs (Gairhe et al. 2018; Baral 2019; Subedi et al. 2020). Small-scale conventional farming, lack of improved cultivars, insufficient technical knowledge, limited extension services, and the incidence of rhizome rot and bacterial wilt are the key problems of ginger production in Nepal (USAID 2011; NARC 2014; Basnet & Gurung 2018). Rhizome rot and bacterial wilt are the common and devastating diseases of ginger that can cause more than 50% yield losses (Dohroo 2005; Stirling et al. 2009; NARC 2014). All these existing problems have constrained ginger yield below 15 $t \cdot ha^{-1}$.

To meet the growing demand for food, there is a need to increase the yield and quality of food crops from a limited area (Tilman et al. 2011; FAO 2017; Calicioglu et al. 2019). The green revolution with the greater use of production inputs such as chemical pesticides and fertilizers, irrigation, new crop cultivars, genetically modified seeds, and improved technologies have significantly increased crop yield worldwide. However, the use of excessive amounts of synthetic pesticides and fertilizers in subsistence types of farming does not seem sustainable in the long term. Those chemical inputs can degrade soil, increase the concentration of toxins in ground and surface water, impose a risk to human health, damage the terrestrial and aquatic ecosystem, and increase production cost (Millennium Ecosystem Assessment 2005; Pimm et al. 2014; Jensen et al. 2020). Moreover, consumers are now more concerned about food safety and quality. Therefore, there is a need to find sustainable technologies that can help to increase yield and to protect our ecosystem and human health.

More importantly, the existing yield gap can be minimized by adopting best management practices (van Ittersum et al. 2013; van Wart et al. 2013; van Bussel et al. 2015). However, these practices should be economically viable and environmentally friendly. Organic farming is one of the sustainable production systems, but it could be expensive for small farmers of Nepal (Rana Bhat 2009; Banjara 2016). In this context, good agricultural practice (GAP) could be a better alternative to organic farming.

The GAP is a set of principles that apply to the farm production and post-production processes to produce safe and healthy food and non-food agriculture products, considering economic, social, and environmental sustainability (Hobbs 2003). A recent study conducted by Bairagi et al. (2019) found that the adoption of GAP could increase farm income by 6.2% and decrease the use of synthetic fertilizers by 31% for rice, lentil, tomato, and ginger in Nepal.

Many developed countries, such as Denmark, Australia, and the United States, have adopted the GAP package for integrated pest and nutrient management for decades (Waage 1998; Zalucki et al. 2009; Remáč 2018). In Turkey, GAP has been implemented as an alternative to organic farming (Akkaya et al. 2005). Also, in several Asian countries such as Nepal, India, Indonesia, Malaysia, Philippines, and Thailand, the GAP system has been implemented particularly in vegetable farming, focusing more on integrated pest and soil fertility management.

The Agriculture Development Strategy 2015–2035 of the Government of Nepal has given priority to GAP as a sustainable farming practice with the main focus on integrated plant nutrient and pest management (MOAD 2015). The Government of Nepal, Ministry of Agriculture, and Food and Agriculture Organization (FAO) have been promoting GAP through a participatory approach that is by organizing farmers' field school (FFS) in some districts as a demonstration.

Many studies have found the positive impact of FFS on improving farmers' knowledge and increasing the yield and income of small farmers (Godtland et al. 2004; Erbaugh et al. 2010; Davis et al. 2012). The participatory approach is considered an effective way to transfer knowledge-intensive technologies (Feder et al. 2003; Athipanyakul & Pak-Uthai 2012; Islam et al. 2012). In FFS, farmers gain practical experiences and improve their knowledge through a "learning-by-doing" approach where they work together in the field to reduce pesticide use, improve crop management, and secure better profit margins. It allows farmers to observe, measure, analyze, assess, and interpret key agro-ecosystem relationships as a basis for making informed management decisions (Braun et al. 2006).

However, due to limited government programs and the lack of GAP knowledge and awareness, the adoption of GAP is limited to very selected areas of Nepal. Moreover, to date, there is no scientific evidence found on the effect of GAP on ginger production.

Realizing the limitations of conventional farming and the importance of GAP, this study aimed to promote sustainable technology among ginger farmers of Nepal through a learning-by-doing approach. The main objective of this study was to compare the yield of ginger under different management practices and recommend the best practice in terms of yield, income, and environment.

MATERIALS AND METHODS

Study site

A 3-year (2016–2018) field-based participatory research was conducted in two major ginger production pocket areas in the Ilam district of Nepal. The experiment sites were located on a similar soil (sandy loam) at a distance of 20 km. One location was 1300 m above sea level and the average temperature in the growing season was 22 °C, and the other location was 1050 m above sea level and the temperature was 25 °C. In both locations, the total rainfall was 215 mm. Soil fertility status was different, but all experiments were located on the acidic soil with medium or high content of organic matter, medium or high nitrogen and potassium status, and medium or low phosphorus status. These differences were equated by different doses of organic and mineral fertilization taken on the base of soil analyses.

Good agricultural practice

In this study, the GAP is defined as a package of sustainable and eco-friendly farming practices focusing on integrated fertilizer management and pest control with the minimum use of chemical production inputs and optimum use of locally available natural resources like plant extracts, biopesticides, and vermicompost. The GAP guidelines developed by the Ministry of Agriculture Development and FAO were reviewed, and a 16-week-long GAP curriculum was developed and implemented throughout the ginger growing period.

Participatory research approach

The applied research study was carried out through the direct participation of farmers who have been growing ginger as their major cash crop. The aim of conducting a participatory research approach was to demonstrate GAP technologies through the FFS approach. Fifty ginger farmers were selected and trained by the GAP experts. Among them, 63% were female participants. They were responsible for growing ginger throughout the research period following GAP guidelines. Two trained GAP facilitators were assigned to organize farmer field school every week throughout the growing period. Facilitators were responsible for instructing farmers, supervising their field activities, managing demonstration plots, and collecting the data.

Experimental design and treatments

The experiment was conducted in a randomized complete block design with five replications. Four treatments were assigned randomly to each replication: T1 – traditional practice with mother rhizome harvest (during growth); T2 – traditional practice without mother rhizome harvest; T3 – GAP with mother rhizome harvest; and T4 – GAP without mother rhizome harvest.

There were similar management practices that adopted for T1 and T2 and for T3 and T4 except for mother rhizome harvest. There were two plots in one farmers' field and three plots in another farmers' field. The area of each plot was 10 m^2 (5 m length and 2 m width). The planting beds were raised to 15 cm high to avoid water logging during the rainy season. The rhizomes were planted at 30 cm × 45 cm spacing. There were four rows with 15 plants per row and 60 plants per plot. Data were collected from the inner two rows. The outer two rows were considered border ones. The traditional practice in this study was defined as the farmers' existing practice.

Field preparation and fertilization

Before planting, soil samples were collected from the plow layer (0–15 cm) of each plot and tested in the Soil Testing Laboratory, Surunga, Nepal, for determination of soil pH, soil organic matter, N, P, and K concentrations. The average soil pH and organic matter content of each plot were 5.1% and 4.4%, respectively (Table 1). For T3 and T4 treatments, the recommended amount of agricultural lime, compost, nitrogen (N), phosphorus (P), and potassium (K) was applied to maintain uniform soil fertility status (Table 2).

Table 1. Soil fertility status of the experimental plots

Plot	Soil Type	Soil pH		Organic matter content		Nitrogen (N)		Phosphorus (P)		Potassium (k)	
		scale	status	%	status	%	status	$g \cdot ha^{-1}$	status	$kg \cdot ha^{-1}$	status
Plot 1	sandy loam	5	acidic	3.9	medium	0.2	medium	23.8	low	156	medium
Plot 2	sandy loam	5.1	acidic	3.7	medium	0.2	medium	28.3	low	336	high
Plot 3	sandy loam	5.2	acidic	5.8	high	0.3	high	38.5	medium	300	high
Plot 4	sandy loam	4.9	acidic	6.1	high	0.3	high	25.6	low	307	high
Plot 5	sandy loam	5.1	acidic	2.6	medium	0.1	medium	22.4	low	226	medium

Table 2. Recommended fertilizers for each experimental plot by Soil Testing Laboratory, Surunga, Nepal

Plot	Recommended fertilizers for ginger cultivation				
	agricultural lime ($t \cdot ha^{-1}$)	compost ($t \cdot ha^{-1}$)	nitrogen ($kg \cdot ha^{-1}$)	phosphorous ($kg \cdot ha^{-1}$)	potassium ($kg \cdot ha^{-1}$)
Plot 1	3.4	12	15	30	30
Plot 2	3.3	12	15	30	15
Plot 3	3.1	6	7.5	15	15
Plot 4	3.6	6	7.5	30	15
Plot 5	3.3	12	15	30	30

In this study, sources of N, P, and K fertilizers were urea (46% N), diammonium phosphate (DAP) (18% N and 46% P), and muriate of potash (MOP) (60% K). Agricultural lime (limestone) dust was applied 1 month before planting. Each plot was plowed two times at a week interval before planting. For T1 and T2, well-decomposed farmyard manure (FYM) was applied at the rate of 25 $t \cdot ha^{-1}$ and N : P : K at the rates of 75 : 50 : 50 $kg \cdot ha^{-1}$, respectively. Urea and MOP were applied in two split doses: the first half was applied 1 month after planting and the remaining half after 2 months of the planting (after harvesting mother rhizome in T1 and T3). Farmyard manure and DAP were applied during the plantation. We also used vermicompost as an improved compost for T3 and T4. It was applied at the rate of 500 g per plant during planting time and after 2 months of planting. The vermicompost was prepared with the used certain species of earthworms for converting cow dung and other organic waste materials into humus.

Planting and disease management

A locally available ginger cultivar called ‘Bose’ was selected for this study. Ginger rhizomes having an average weight of 80 g were selected for T1 and T2 and 60 g with at least one bud on it were selected for T3 and T4. The selected rhizomes were then treated with systemic fungicide (Carbendazim 50% WP) solution for T1 and T2 and bio-fungicide (*Trichoderma viride* and *Azadirachta indica* 1.5 WP) solution for T3 and T4 (Table 3). The treated rhizomes were then planted on the raised bed maintaining 30 cm plant-to-plant distance and 45 cm row-to-row distance. Immediately after planting, beds were mulched with straw, grasses, and other plant materials. Every week, the farmers gathered in the field where the GAP facilitators facilitated them to adopt GAP technology step by step. Farmers themselves were able to produce vermicompost, compost, and plant extract and their application procedures.

For T1 and T2 treatments, only chemical pesticides were used for seed treatment and pest control in the field, but for T3 and T4 treatments, mostly organic pesticides were used (details in Table 3). In T1 and T2 plots, Cypermethrin 25% EC solution was used for insect control and Metalaxyl 35% WS for rhizome rot and other fungal disease control. For T3 and T4 treatments, plant extract, an organic insecticide, was used for insect control and Validamycin 3% L, an antibiotic, was used to control rhizome rot and other fungal and bacterial diseases. The plant extract was prepared from the bitter, sour, spicy, and salty types of plant materials, such as tobacco, neem (*Azadirachta indica*), and hot chili after fermenting them with cow urine for 10–15 days.

Table 3. Pesticides application details of this research experiment

Fungicide; insecticide	Treatment	Formulation	Method and time of application	Frequency of application
Carbendazim 50% WP	T1 and T2	3 g·L^{-1} water	The seed rhizome was dipped in the formulated solution for 3–5 minutes and dried in the shadow before planting	one time during seed treatment
Trichoderma viride 1.5 WP	T3 and T4	5 g·L^{-1} water	Same as above but used *Trichoderma* instead of carbendazim. For compost making, the formulated solution was sprayed over the compost pit and then the pit was covered by plant materials or black colored plastic for at least one week before the application	one time during seed treatment and one time during compost making
Metalaxyl 35% WS	T1 and T2	2.5 g·L^{-1} water	Foliar sprayed when disease symptoms appeared	3 times at intervals of 10 days
Validamycin 3% L	T3 and T4	2.5 g·L^{-1} water	Foliar sprayed when disease symptoms appeared	3 times at intervals of 10 days
Cypermethrin 25% EC	T1 and T2	2.5 mL·L^{-1} water	Foliar sprayed when insect and borer appeared	3 times at intervals of 10 days
Plant extracts	T3 and T4	10 mL·L^{-1} water	Foliar sprayed starting after one month of planting	regularly at intervals of 2 weeks

All other intercultural operations in T1 and T2 were followed as per the farmers' existing practices, whereas GAP guidelines were followed in T3 and T4. Mother rhizomes were harvested after 2 months from T1 and T3 treatment plots. The final harvesting was done about 250 days after planting.

Benefit–cost analysis

The benefit–cost (BC) analysis was estimated to analyze the value of money of each treatment. The net farm income and benefit–cost ratio were calculated based on the local market price, farmers' information, and the average yield obtained from this study. Land lease and farm equipment were considered fixed costs, whereas production material cost, seasonal labor, and marketing cost were considered variable costs. The treatment-wise variable cost and the gross income obtained from the sale of mother and new ginger rhizome were recorded separately each year and then converted to the cost and income per hectare per year. The net income per hectare was simply calculated for each year by deducting gross income with the total cost (total fixed cost and total variable cost). The average of 3 years' net income of each treatment was then considered the net income of each treatment. The BC ratio was calculated by dividing 3 years' average gross income by the average total cost. For the decision-making process, the BC ratio greater than 1 indicates that farmers obtained a profit, whereas the BC ratio smaller than 1 indicates that farmers had not, and it should not be considered for further investment or production. In addition to BC, we also collected 5 years' market price information of ginger from Kalimati Fruits and Vegetable Wholesale Market, Kathmandu, Nepal, to examine whether higher net income was due to the high market price or increased yield or the combination of both. We also compared the net farm income of the ginger produced under GAP by harvesting mother rhizome with other possible alternative crops for that research area. The cost of production and net farm income of other crops were taken from previous studies conducted in Nepal.

Statistical analysis

SAS Proc GLIMMIX procedure was used to estimate fix effect, interaction effect, and treatment-wise mean yield differences (Isik 2011). We used ginger yield as dependent variables and production year, location, and treatments as independent variables to interpret the relationship between those dependent and independent variables. Based on the soil test report and local weather conditions, plots were considered homogeneous. We also checked the interaction effect of production year and location with treatments to minimize errors due to different production environments. LS means were computed to compare the effect of each treatment on ginger yield. The statistical comparisons were made at a 5% level of significance.

RESULTS

The only significant differences at the 5% level were recorded for applied treatments (Table 4). No significant effects were obtained for the effects of location and the year of the experiment as well as for their interactions.

Figure 1 shows that T4 treatment resulted in a significantly higher rhizome yield (17.9 t·ha^{-1}) but did not differ statistically from T3 (17.5 t·ha^{-1}). The rhizome yield of GAP treatments was significantly different from traditionally produced rhizomes (T1 12.3 and T2 12.8 t·ha^{-1}). The study results showed a yield gap of 5.1 t·ha^{-1} between the potential yield and the farmer's actual yield. Likewise, the yields from treatments were about 2–4% higher if the mother rhizome was not harvested.

Table 4. Analysis of variance results on ginger yield as affected by production year, location, treatment, and their interactions

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Year	2	0.27	0.13	0.8	NS
Location	1	0.07	0.07	0.42	NS
Treatment	3	396.59	132.19	771.58	***
Year × Treatment	6	0.77	0.12	0.74	NS
Location × Treatment	3	0.05	0.01	0.09	NS
Year × Location × Treatment	6	0.72	0.12	0.96	NS
Residuals	38	5.48	0.17		NS

*** significant at 0.01; NS: not significant

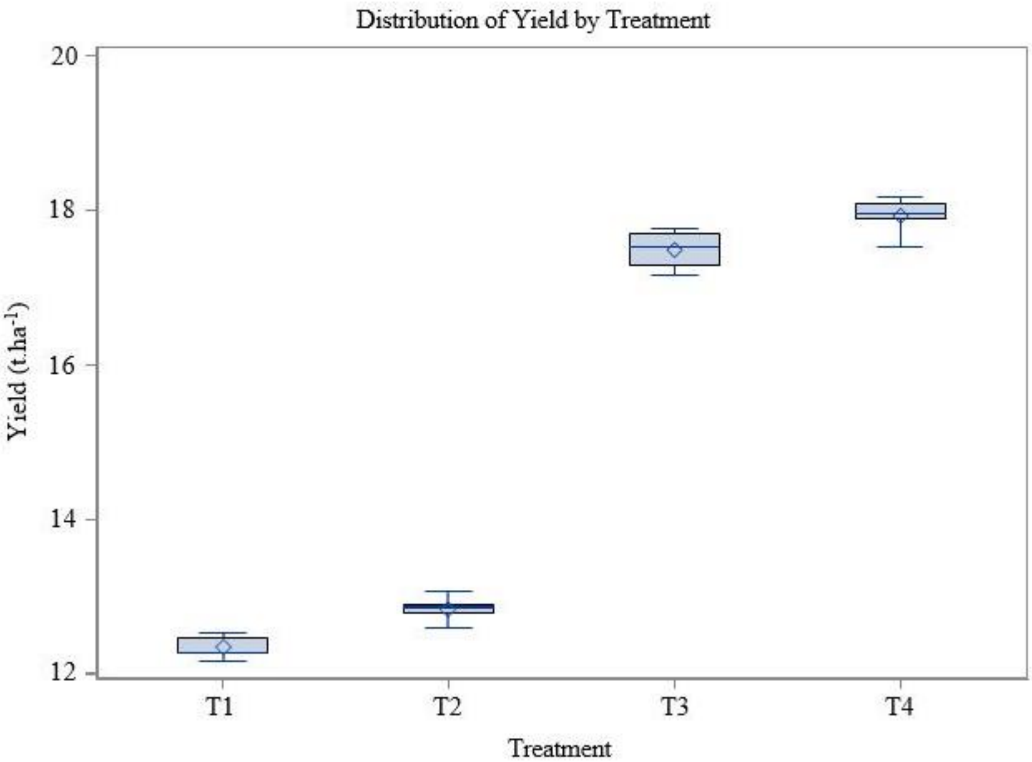

Fig. 1. Distribution of ginger yield (mean, quartiles, and minimum and maximum) affected by treatment. Treatments included traditional practice with mother rhizome harvest (T1), traditional practice without mother rhizome harvest (T2), GAP with mother rhizome harvest (T3), and GAP without mother rhizome harvest (T4)

Net farm income and benefit–cost ratio

Table 5 shows that the T3 treatment provided the highest net income ($2072.6·ha^{-1}·year^{-1}) even though the yield of T4 treatment was the highest. Also, the BC ratio of T3 was found the highest (1.5) which means that growing ginger by adopting GAP with mother rhizome harvest practice gave the highest profit to the farmers comparing with the other three management practices. In contrast, T2 treatment resulted in the lowest net income ($16.7·ha^{-1}·year^{-1}) and the lowest BC ratio (1.0) while considering their own contribution and fixed asset in the cost items.

Table 5. Cost-benefit analysis of ginger under different farming practices in Ilam district of Nepal

Treatment	Rhizome yield (t·ha^{-1})	Gross income ($·ha^{-1})	Total fixed cost ($·ha^{-1})	Total variable cost ($·ha^{-1})	Total cost ($·ha^{-1})	Net income ($·ha^{-1})	BC ratio
T1	12.3	4638.1	523.8	3282.4	3806.2	831.9	1.2
T2	12.8	3657.1	523.8	3116.7	3640.5	16.7	1.0
T3	17.5	5933.3	523.8	3336.9	3860.7	2072.6	1.5
T4	17.9	5114.3	523.8	3298.3	3822.1	1292.1	1.3

Note: 1 US dollar is the equivalent of NRs. 105 (Nepalese currency)

DISCUSSION

The crop yield depends on many contributing factors such as weather, plant genotype, and management practice. In this experiment, we used high-yielding selected local cultivar, bio-pesticides, and chemical fertilizers and pesticides based on the actual need, dose, and soil fertility status. All other intercultural operations were followed as per the calendar of operations listed on GAP guidelines. The average growing season temperature and rainfall were found similar in each year of the experiment. Thus, we did not find a significant yield difference between three consecutive years of experiment. Similarly, the distance between the two locations was about 20 km where we found homogeneous soil types and weather patterns. Therefore, we also observed a similar yield in both locations.

But the yield and income varied greatly between traditional and GAP-adopted treatments and, to a lesser extent, between mother rhizome-harvested and not-harvested treatments. The higher yield obtained from the GAP in this study is consistent with the findings of Basnet & Gurung (2018) who reported a similar yield (17–22 t·ha^{-1}) of ginger in western Nepal under different management practices, including the use of improved ginger cultivar, mother rhizome harvest, and the use of *Trichoderma* and vermicompost.

Many studies have reported that vermicompost could be used as an alternative to synthetic fertilizers because it has a positive effect on improving soil fertility and yield of various crops (Alam et al. 2007; Manivannan et al. 2009; Isaac & Varghese 2016; Esmaielpour et al. 2020). Turmeric rhizome yields were found significantly highest (42.71 t·ha^{-1}) in the treatment applying vermicompost along with synthetic fertilizers in southern India (Isaac & Varghese 2016). Similarly, some studies found that various *Trichoderma* species are effective to manage rhizome rot disease in ginger and turmeric (Bharathi & Sudhakar 2011; Acharya et al. 2016; Thakur et al. 2017).

Application of *Trichoderma* solution can replace partly synthetic pesticides and insecticides (Tomer et al. 2018; Shashikumar et al. 2019; Maurya et al. 2020). The average yield of rice grown under GAP was increased by 1 t·ha^{-1} in 2013 and 2.7 t·ha^{-1} in 2014 comparing with the yield obtained from farmer's own practices in Tanzania (Senthilkumar et al. 2018). Islam et al. (2012) found higher yield and income (1.7 times higher) from GAP-adopted tomato farming in Malaysia. Based on our results and previous study findings, we can confirm that good agricultural practices, such as integrated pest and soil nutrient management practices, improve ginger yield and net farm income.

Farmers remove mother rhizome during the rainy season (May–June) when the average temperature is usually 25 °C, relative humidity is above 70%, and soil moisture is high. This is a favorable condition to outbreak rhizome rot disease (Stirling et al. 2009; Le et al. 2014; Hossain et al. 2015). Moreover, the mother rhizome plays a vital role in the growth and development of plants because it reserves carbohydrates and protein (Gallagher et al. 1984; Steinmann & Brändle 1984; Le et al. 2014). The mother rhizome harvest in the main growth stage could cause mechanical injury, poor root growth, and decrease food reserve in the plant and ultimately leads to an increase in the chance of rhizome rot and other disease infection and yield reduction. Thus, the existing practice of mother rhizome harvest could be one of the reasons behind lower yield under T1 and T3 treatments.

Furthermore, the total production costs were almost similar in both traditional and under the GAP rules. But, the net farm income per hectare was found to be higher in the GAP treatments because the yield there was about 5 $t \cdot ha^{-1}$ higher than that under the traditional practices. Comparably, the net farm income from mother rhizome-harvested treatments was much higher than that from the non-harvested treatments. The net farm income per hectare in GAP with mother rhizome harvest (T3) was more than twice as high ($2072.6) as in traditional practice (T1). It is because the ginger price is usually above $\$250 \cdot t^{-1}$ higher during the time of mother rhizome harvesting and marketing than at the normal harvesting time (MOALD 2020). This is the main reason for harvesting mother rhizome in Nepal. Hence, the higher net income gained from the GAP with mother rhizome-harvested treatment in this study was due to increased yield and the higher market price at the mother rhizome marketing period. A similar net income was also reported by various studies conducted in different districts of Nepal (Timsina 2010; Poudel et al. 2016; Acharya et al. 2019). Based on the production cost and net farm income of each treatment, this study showed that the GAP-adopted production costs were not much different from the traditional ones, but the GAP treatments resulted in much higher income.

Table 6 shows that in Nepal the highest income per hectare could be achieved from large cardamom farming followed by ginger. It is true because the market price of large cardamom is much higher than that of other crops grown in this district, but this crop requires a specific production environment such as swampy land with high humidity, frequent irrigation, and shade (Shrestha et al. 2018). Those requirements are available in a limited area only. Thus, this study revealed that ginger production by adopting GAP rules has the comparative advantage in terms of net farm income over other alternative crops grown in Nepal. Therefore, with the government policy and interventions, this technology can be promoted wider. Further studies are needed to examine the potential effect of GAP with different doses of NPK or a combination of NPK with organic fertilizers and with different cultivars on ginger yield.

Table 6. Net farm income of various crops grown in Nepal

Crops	Production cost ($\$ \cdot ha^{-1}$)	Revenue ($\$ \cdot ha^{-1}$)	Net farm income ($\$ \cdot ha^{-1}$)	Reference
Ginger (GAP with mother rhizome harvest)	3860.7	5933.3	2072.6	field survey
Large cardamom	623.0	2952.4	2329.4	Kandel (2019)
Cabbage	1478.6	826.7	826.7	Katovich and Sharma (2014)
Potato	1878.0	2552.8	674.9	Bajracharya and Sapkota (2017)
Tomato	1823.5	2344.4	521.0	Katovich and Sharma (2014)
Cucumber	2119.5	3795.8	1676.3	Katovich and Sharma (2014)
Pigeon pea	617.8	906.7	305.8	MOAD (2017)
Tea	4718.4	5780.0	1061.6	Baral (2019)
Rice	543.0	757.4	214.4	Katovich and Sharma (2014)
Maize	467.8	526.6	58.7	Katovich and Sharma (2014)

Note: see Table 5

CONCLUSION

This study revealed that the ginger yield can be increased by 46% when grown under GAP rules without harvesting mother rhizomes. But, the highest net farm income (up to 60%) can be obtained from the GAP with mother rhizome harvest practice. Increased yield, higher BC ratio along with maximum net farm income, lower use of chemical inputs, high market price during mother rhizome harvesting time, and comparative benefit over other alternative crops found in the ginger farming adopting GAP with mother rhizome harvesting practice indicate that this practice could be the most profitable and sustainable farming practice for the ginger producers.

REFERENCES

Acharya B., Regmi H., Ngangbam A.K., Nongmaithem B.D. 2016. Management of rhizome rot disease of ginger using eco-friendly natural products. Indian Journal of Agricultural Research 50(6): 599–603. DOI: 10.18805/ijare.v0iof.3757.

Acharya N., Acharya B., Dhungana S.M., Bist V. 2019. Production economics of ginger (*Zingiber officinale* Rose.) in Salyan district of Nepal. Archives of Agriculture and Environmental Science 4(4): 424–427. DOI: 10.26832/24566632.2019.040408.

Akkaya F., Yalcin R., Ozkan B. 2005. Good agricultural practices (GAP) and its implementation in Turkey. Acta Horticulturae 699: 47–52. DOI: 10.17660/actahortic.2006.699.3.

Alam M.N., Jahan M.S., Ali M.K., Islam M.S., Khandaker S.M.A.T. 2007. Effect of vermicompost and NPKS fertilizers on growth, yield and yield components of red amaranth. Australian Journal of Basic and Applied Sciences 1(4): 706–716.

Athipanyakul T., Pak-Uthai W. 2012. Determinants of good agricultural practices (GAP) adoption in the chili production system in Northeastern Thailand: A case of participatory approach. International Journal of Environmental and Rural Development 3(2): 175–180.

Bairagi S., Mishra A.K., Giri A. 2019. Good agricultural practices, farm performance, and input usage by smallholders: Empirical evidence from Nepal. Agribusiness 35(3): 471–491. DOI: 10.1002/agr.21577.

Bajracharya M., Sapkota M. 2017. Profitability and productivity of potato (*Solanum tuberosum*) in Baglung district, Nepal. Agriculture and Food Security 6(1); 47; 8 p. DOI: 10.1186/s40066-017-0125-5.

Banjara R.K. 2016. Challenges of organic farming faced by Nepalese farmers. International Journal of Agricultural Extension and Rural Development Studies 3(4): 31–37.

Baral R.B. 2019. Nepal Orthodox Tea: Analysis of industry, production, and market potential. M.S. thesis. Kansas State University, USA, 106 p. https://krex.k-state.edu/dspace/handle/2097/40271 (accessed March 11, 2021)

Basnet M., Gurung H. 2018. Influence of mother rhizome retrieval and organic treatment of the retrieved plants on economic yield of ginger at Salyan, Nepal. Journal of the Institute of Agriculture and Animal Science 35(1): 203–209. DOI: 10.3126/jiaas.v35i1.22542.

Bharathi V., Sudhakar R. 2011. Management of rhizome rot of turmeric (*Curcuma longa* L.) through IDM practices. Annals of Plant Protection Sciences 19(2): 400–402.

Braun A., Jiggins J., Röling N., van den Berg H., Snijders P. 2006. A global survey and review of farmer field school experiences. Report prepared for the International Livestock Research Institute (ILRI). Wageningen, the Netherlands, 91 p.

Calicioglu O., Flammini A., Bracco S., Bellù L., Sims R. 2019. The future challenges of food and agriculture: An integrated analysis of trends and solutions. Sustainability 11(1); 222; 21 p. DOI: 10.3390/su11010222.

Davis K., Nkonya E., Kato E., Mekonnen D.A., Odendo M., Miiro R., Nkuba J. 2012. Impact of farmer field schools on agricultural productivity and poverty in East Africa. World Development 40(2): 402–413. DOI: 10.1016/j.worlddev.2011.05.019.

Dohroo N.P. 2005. Diseases of ginger. In: Ravindran P.N., Nirmal Babu K. (Eds.), Ginger: the Genus Zingiber. CRC Press, USA, pp. 305–340.

Erbaugh J.M., Donnermeyer J., Amujal M., Kidoido M. 2010. Assessing the impact of farmer field school participation on IPM adoption in Uganda. Journal of International Agricultural and Extension Education 17(3): 5–17. DOI: 10.5191/jiaee.2010.17301.

Esmaielpour B., Einizadeh S., Pourrahimi G. 2020. Effects of vermicompost produced from cow manure on the growth, yield and nutrition contents of cucumber (*Cucumis sativus*). Journal of Central European Agriculture 21(1): 104–112. DOI: 10.5513/jcea01/21.1.2121.

FAO 2017. The future of food and agriculture: Trends and challenges. Food and Agriculture Organization of the United Nations, Rome, Italy, 163 p.

FAOSTAT 2020. Data: Crops. Food and Agriculture Organization of the United Nations, Rome, Italy. http://www.fao.org/faostat/en/#data/QC (accessed June 20, 2020)

Feder G., Murgai R., Quizon J. 2003. Sending farmers back to school: The impact of farmer field schools in Indonesia. Policy Research Working Paper 3022, the World Bank, 41 p.

Gairhe S., Shrestha H.K., Timsina K. 2018. Dynamics of major cereals productivity in Nepal. Journal of Nepal Agricultural Research Council 4: 60–71. DOI: 10.3126/jnarc.v4i1.19691.

Gallagher J.L., Wolf P.L., Pfeiffer W.J. 1984. Rhizome and root growth rates and cycles in protein and carbohydrate concentrations in Georgia *Spartina alterniflora* Loisel. plants. American Journal of Botany 71(2): 165–169. DOI: 10.1002/j.1537-2197.1984.tb12500.x.

Godtland E.M., Sadoulet E., de Janvry A., Murgai R., Ortiz O. 2004. The impact of farmer-field-schools on knowledge and productivity: A study of potato farmers in the Peruvian Andes. Economic Development and Cultural Change 53(1): 63–92. DOI: 10.1086/423253.

Hobbs J.E. 2003. Incentives for the adoption of good agricultural practices (GAPs). Background paper for the FAO Consultation on Good Agricultural Practices. Food and Agriculture Organization of the United Nations, 10–12 November 2003, Italy, 27 p. http://www.fao.org/23/ag854e/ag854e800.htm (accessed June 25, 2020)

Hossain S.M.M., Hasan M.M., Alam M.A., Islam M.M. 2015. Study on epidemiology and chemical control of rhizome rot disease of ginger (*Zingiber officinale* Rose). Journal of Science and Technology 13: 75–81.

Isaac S.R., Varghese J. 2016. Nutrient management in turmeric (*Curcuma longa* L.) in an integrated farming system in southern Kerala. Journal of Spices and Aromatic Crops 25(2): 206–209.

Isik F. 2011. Generalized linear mixed models: An introduction for tree breeders and pathologists. IV International Workshop on the Genetics of Host–Parasite Interactions in Forestry, July 31 – August 5, USA, 47 p.

Islam G.M.N., Arshad F.M., Radam A., Alias E.F. 2012. Good agricultural practices (GAP) of tomatoes in Malaysia: Evidences from Cameron Highlands. African Journal of Business Management 6(27): 7969–7976. DOI: 10.5897/ajbm10.1304.

Jensen E.S., Carlsson G., Hauggaard-Nielsen H. 2020. Intercropping of grain legumes and cereals improves the use of soil N resources and reduces the requirement for synthetic fertilizer N: A global-scale analysis. Agronomy for Sustainable Development 40(1); 5; 9 p. DOI: 10.1007/s13593-020-0607-x.

Kandel S. 2019. Economics of production and marketing of organic large cardamom in Panchthar district of Nepal. Acta Scientific Agriculture 3(8): 133–144. DOI: 10.31080/asag.2019.03.0574.

Katovich E., Sharma A. 2014. Costs and returns of grain and vegetable crop production in Nepal's Mid-Western Development Region. https://conservancy.umn.edu/bitstream/handle/11299/165366/KatovichE.pdf (accessed March 11, 2021)

Le D.P., Smith M., Hudler G.W., Aitken E. 2014. Pythium soft rot of ginger: Detection and identification of the causal pathogens, and their control. Crop Protection 65: 153–167. DOI: 10.1016/j.cropro.2014.07.021.

Li H., Liu Y., Luo D., Ma Y., Zhang J., Li M. et al. 2019. Ginger for health care: An overview of systematic reviews. Complementary Therapies in Medicine 45: 114–123. DOI: 10.1016/j.ctim.2019.06.002.

Manivannan S., Balamurugan M., Parthasarathi K., Gunasekaran G., Ranganathan L.S. 2009. Effect of vermicompost on soil fertility and crop productivity – beans (*Phaseolus vulgaris*). Journal of Environmental Biology 30(2): 275–281

Maurya S., Rai D., Dubey S., Pal R.K. 2020. Compatibility of *Trichoderma harzianum* with different fungicides under *in vitro*. International Journal of Chemical Studies 8(1): 2946–2949. DOI: 10.22271/chemi.2020.v8.i1as.8716.

Millennium Ecosystem Assessment 2005. Ecosystems and human well-being: Synthesis. A Report of the Millennium Ecosystem Assessment, Island Press Washington, USA. https://www.millenniumassessment.org/documents/document.356.aspx.pdf (accessed July 27, 2020)

MOAD 2015. Agriculture Development Strategy (ADS) 2015 to 2035. Government of Nepal, Ministry of Agricultural Development. Kathmandu, Nepal. http://faolex.fao.org/docs/pdf/nep171433.pdf

MOAD 2017. Statistical Information on Nepalese Agriculture 2015/16. Government of Nepal, Ministry of Agricultural Development. Monitoring, Evaluation and Statistics Division, Kathmandu, Nepal, 207 p. https://www.moald.gov.np/publication/Agriculture%20Statistics (accessed March 11, 2021)

MOALD 2018. Statistical Information on Nepalese Agriculture 2016/17. Government of Nepal, Ministry of Agriculture and Livestock Development. Planning and Development Cooperation Coordination Division Statistical Analysis Section, Kathmandu, Nepal, pp. 41–45. https://www.moald.gov.np/publication (accessed June 25, 2020)

MOALD 2020. Commodity Wise Price Information. Government of Nepal, Ministry of Agriculture and Livestock Development. Kalimati Fruits and Vegetable Market Development Board. https://kalimatimarket.gov.np/commodity-wise-price-information (accessed June 15, 2020)

MOC 2016. Nepal Trade Integration Strategy 2016. Government of Nepal, Ministry of Commerce. Kathmandu, Nepal. https://www.oecd.org/aidfortrade/countryprofiles/dtis/Napal-DTIS-2016.pdf (accessed June 10, 2020)

NARC 2014. Annual Report 2013/14. Government of Nepal, Nepal Agricultural Research Council. Ginger Research Programme. Salyan, Nepal.

Niebyl J.R., Goodwin T.M. 2002. Overview of nausea and vomiting of pregnancy with an emphasis on vitamins and ginger. American Journal of Obstetrics and Gynecology 186(5): 253–255. DOI: 10.1067/mob.2002.122595.

Pimm S.L., Jenkins C.N., Abell R., Brooks T.M., Gittleman J.L., Joppa L.N. et al. 2014. The biodiversity of species and their rates of extinction, distribution, and protection. Science 344(6187); 987; 1246752, 11 p. DOI: 10.1126/science.1246752.

Poudel R.R., Regmi P.P., Thapa R.B., Chhetri Y.D.G., Chhetri D.B.K. 2016. Economic analysis of ginger cultivation in selected locations of Palpa, Nepal. Azarian Journal of Agriculture 3(6): 135–140.

Rana Bhat B. 2009. Opportunity and challenge of organic certification system in Nepal. Journal of Agriculture and Environment 10: 124–128. DOI: 10.3126/aej.v10i0.2139.

Remáč M. 2018. Directive 2009/128/EC on the sustainable use of pesticides. Study. European Implementation Assessment. European Parliamentary Research Service, European Parliament, 192 p.

SAS Institute 2015. Base SAS 9.4 Procedures Guide. Statistical Procedures, fourth ed. SAS Institute, USA.

Senthilkumar K., Tesha B.J., Mghase J., Rodenburg J. 2018. Increasing paddy yields and improving farm management: results from participatory experiments with good agricultural practices (GAP) in Tanzania. Paddy and Water Environment 16(4): 749–766. DOI: 10.1007/s10333-018-0666-7.

Shashikumar H.M., Koulagi S., Navyashree S.E. 2019. Compatibility of *Trichoderma viride* and *Trichoderma harzianum* with fungicides against soil borne diseases of tomato and cabbage. International Journal of Current Microbiology and Applied Sciences 8(4): 1920–1928. DOI: 10.20546/ijcmas.2019.804.225.

Shrestha J., Prasai H.K., Timsina K.P., Shrestha K.P., Pokhrel D., Poudel K., Yadav M.P. 2018. Large cardamom in Nepal: Production practice and economics, processing and marketing. Government of Nepal, Nepal Agricultural Research Council. National Commercial Agriculture Research Program. Dhankuta, Nepal.

Singletary K. 2010. Ginger: An overview of health benefits. Nutrition Today 45(4): 171–183. DOI: 10.1097/nt.0b013e3181ed3543.

Steinmann F., Brändle R. 1984. Carbohydrate and protein metabolism in the rhizomes of the bulrush (*Schoenoplectus lacustris* (L.) Palla) in relation to natural development of the whole plant. Aquatic Botany 19(1–2): 53–63. DOI: 10.1016/0304-3770(84)90007-x.

Stirling G.R., Turaganivalu U., Stirling A.M., Lomavatu M.F., Smith M.K. 2009. Rhizome rot of ginger (*Zingiber officinale*) caused by *Pythium myriotylum* in Fiji and Australia. Australasian Plant Pathology 38(5): 453–460. DOI: 10.1071/ap09023.

Subedi R., Karki M., Panday D. 2020. Food system and water–energy–biodiversity nexus in Nepal: A review. Agronomy 10(8); 1129; 19 p. DOI: 10.3390/agronomy10081129.

Thakur A., Thakur N., Dohroo N.P. 2017. Rhizome rot of ginger-management through non-chemical approach. International Journal of Plant Protection 10(1): 140–145. DOI: 10.15740/has/ijpp/10.1/140-145.

Tilman D., Balzer C., Hill J., Befort B.L. 2011. Global food demand and the sustainable intensification of agriculture. Proceedings of the National Academy of Sciences 108(50): 20260–20264. DOI: 10.1073/pnas.1116437108.

Timsina K.P. 2010. Economics of ginger production: A case study of Makawanpur district, Nepal. Journal of the Institute of Agriculture and Animal Sciences 31–32: 35–41.

Tomer A., Singh R., Prasad D. 2018. Compatibility *Trichoderma harzianum* with systemic and two non systemic fungicides of *in vitro*. Asian Journal of Crop Science 10(4): 174–179. DOI: 10.3923/ajcs.2018.174.179.

USAID 2011. Value chain/market analysis of the ginger sub-sector in Nepal. Nepal Economic Agriculture, and Trade Activity. United States Agency for International Development. General Development Office, Kathmandu, Nepal. https://ansab.org.np/storage/product/nepal-neat-subsector-market-analysis-ginger-aug-2011-1579689425.pdf (accessed July 12, 2020)

van Bussel L.G.J., Grassini P., van Wart J., Wolf J., Claessens L., Yang H. et al. 2015. From field to atlas: Upscaling of location-specific yield gap estimates. Field Crops Research 177: 98–108. DOI: 10.1016/j.fcr.2015.03.005.

van Ittersum M.K., Cassman K.G., Grassini P., Wolf J., Tittonell P., Hochman Z. 2013. Yield gap analysis with local to global relevance – A review. Field Crops Research 143: 4–17. DOI: 10.1016/j.fcr.2012.09.009.

van Wart J., Kersebaum K.C., Peng S., Milner M., Cassman K.G. 2013. Estimating crop yield potential at regional to national scales. Field Crops Research 143: 34–43. DOI: 10.1016/j.fcr.2012.11.018.

Waage J. 1998. The future development of IPM. Entomologia Sinica 5(3): 257–271. DOI: 10.1111/j.1744-7917.1998.tb00322.x.

White B. 2007. Ginger: An overview. American Family Physician 75(11): 1689–1691.

Zalucki M.P., Adamson D., Furlong M.J. 2009. The future of IPM: whither or wither? Australian Journal of Entomology 48(2): 85–96. DOI: 10.1111/j.1440-6055.2009.00690.x.