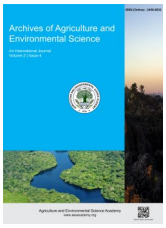
Archives of Agriculture and Environmental Science 6(4): 570-574 (2021)
https://doi.org/10.26832/24566632.2021.0604021

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



REVIEW ARTICLE

A review on maize-finger millet relay cropping in hills of Nepal: Prospects and constraints

Dipika Parajulee[1*] and Sangam Panta[2]

[1]Nepal Polytechnic Institute (NPI), Chitwan, NEPAL [2]Agriculture and Forestry University (AFU), Chitwan, NEPAL
[*]Corresponding author's E-mail: parajuleedipika423@gmail.com

ARTICLE HISTORY

Received: 03 September 2021
Revised received: 28 November 2021
Accepted: 10 December 2021

Keywords

Benefits
Cereal
Cropping system
Hill area
Limitations

ABSTRACT

Maize (*Zea mays*) and Finger millet (*Elusine corocana*) are two key staple crops grown in the hills of Nepal. These crops are planted in a relay intercropping system developed by farmers since the dawn of time. The unique example of cereal-cereal intercropping with its cropping system and cropping pattern at different altitudes is reviewed along with the yield comparison of direct-seeded and transplanted finger millet with maize. Relay cropping is the planting of second crop in the same land area before the harvest of first crop with the goal of higher productivity by sharing the available resources. Considerable research has been done on maize and millet but there has been a limited approach to their cropping system. This paper reviews the existing system of cropping, its prospects, and its constraints. The prospects of maize/finger millet cultivation are pronounced in the form of yield increment, economic and efficient use of available resources, insurance against crop failure, and reduced insect, pest, and weed incidence. Although this cropping system has benefits, it exhibits limitations as well which are competition between crops, lack of suitable varieties, labor-intensive system, and soil-nutrient loss. As maize and finger millet are the main food crops in hilly terrain, it is urged to provide the focus and encouragement regarding their sustainable and modern approaches by developing and disseminating crop growing and management technologies.

©2021 Agriculture and Environmental Science Academy

Citation of this article: Parajulee, D., & Panta, S. (2021). A review on maize-finger millet relay cropping in hills of Nepal: Prospects and constraints. *Archives of Agriculture and Environmental Science*, *6*(4), 570-574, https://dx.doi.org/10.26832/24566632.2021.0604021

INTRODUCTION

Maize (*Zea mays*) and Finger-millet (*Elusine corocana*) is the second and fourth most widely produced cereal crops in Nepal. The total production of maize was 1855184 metric ton (mt) in 2009 AD and 2713635 mt in 2019 AD. The total production of finger millet was 299523 mt in 2009 AD which increased to 314225 mt in 2019 AD (MoAC, 2019). Maize and Millet are the main staple crops of farmers in hilly areas. Millet is rarely mono-cropped and majorly relay intercropped with maize. It is an almost unique example of cereal-cereal relay cropping. Relay cropping is an age-old cultivation system of second crop in the same plot of land before the harvest of first crop sharing resources for all or part of the growing season (Panda, 2010). The extent and importance of intercropping develops as the farm size diminishes. The primary reason for intercropping dominance in hill farming is for high and stable yield as well as income (Yamoah *et al*., 2003) and also to manage weeds because enough area of ground is covered by crops which suppress weed growth (Maitra *et al*., 2020). Nepal is a small land belt country but more yield is expected so, relay intercropping enhances the per unit productivity of the land from the same small parcel (Paudel, 2016).

Relay transplanting of finger millet under existing spring-sown maize is a traditional cropping pattern in hills between 1100 and 1700 meter above sea level (masl) and more than 85% of finger millet is produced in combination with maize under this system. Two distinct land types are found in the region: rainfed Bari land and khet land. Bari land is cultivated unbunded upland on unirrigated valley bottoms whereas khet land is usually bunded for flooding, under various irrigation systems (Shrestha). According to Table 1, maize and millet cropping patterns are found in Bari land type of hill areas.

Table 1. Common hill cropping patterns in the Hill districts of Nepal.

Altitude	Land type	Cropping patterns
<1000m	Bari	Maize-fingermillet-fallow Maize+soyabean-fallow Maize+upland rice-black gram
1000-1500m	Bari	Maize/finger millet-wheat/barley Maize/finger millet-fallow Maize/finger millet-mustard
1500-2400m	Bari	Maize/finger millet-fallow Maize/finger millet-wheat/barley Maize-naked barley- finger millet (2 years) Maize- fallow Potato- fallow

Source: Subedi (1990).

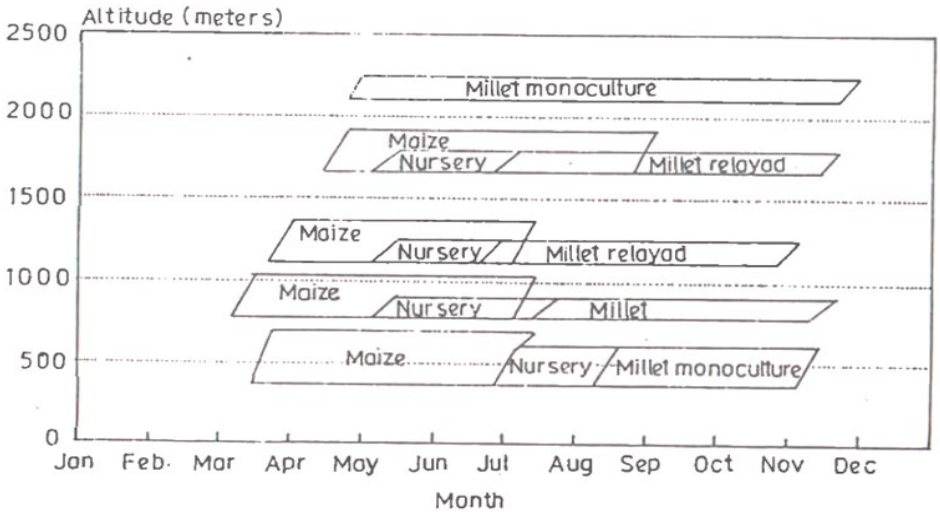


Figure 1. *Effect of altitude on the crop duration and cropping pattern (Source: Sthapit et al., 1991).*

Maize and finger millet relay intercropping is an old practice in Nepal and it is the predominant combination found in hill agriculture. This system has helped maintain food and nutritional security from 500-1800 m since time old. Maize-millet system is advantageous to farmers because of reduced land preparation and more efficient utilization of moisture, nutrient, and labor resources. The system sustained for several years being advantageous to the farmers but this system of cropping exhibits some challenges as well which needs to be minimized to uplift the productivity as well as the fertility of soil. Millet is grown on the residual fertility of maize crop and farmers apply about 10-25 (t/ha/annum) manure to maize (Sthapit and Subedi, 1990). 30 –60 days old seedlings are transplanted under the standing maize in between tasseling stage and grain filling stage at lower altitudes, whereas, at higher altitudes, it is transplanted at knee high stage. The overlapping period of relay cropping becomes longer between maize and millet at higher altitude (Subedi, 2001). Finger millet develops with minimal competition after maize is removed and the exploitation of the available moisture after maize removal is a key to intensify this system (Paudyal *et al.*, 2001). The duration of overlap of maize and millet in the relayed system increases from 30-40 days at 1000 m to 70-80 days at 1500 m (Subedi, 1990). Evidently, the competition between the maize and millet crops is mainly determined by the period that both crops are grown together (Figure 1).

Finger-millet has the potential to improve nutritional and health security of growing population especially to the marginalized, small holder farmers but it is considered as underutilized, minor and neglected crop (Gairhe *et al.*, 2021). Maize and millet intercropping is a dominant system (Upreti, 2001; Paudel *et al.*, 2001; Acharya *et al.*, 2001, Shrestha *et al.*, 2001) in hill areas of the country. Intercropping of maize and millet has greater scope to utilize land, and other resources to maximum intent. Both, maize and finger-millet are summer crops which can provide dietary requirement along with fodder supply for long term.

Production system in hills

Finger millet is grown entirely under rainfed condition by direct seeding or by transplanting either under the standing maize or after maize harvest, depending upon the altitude. Finger millet crop duration ranges from 150 days to 180 days and too early or too late transplanting can lead to sterility of crop (Sthapit *et al.*, 1991). Any weeding necessary is done manually. Maize leaves below the ears are stripped when silks begin to dry, to reduce the shading effect to millet. The production system of maize and finger millet varies according to altitude, land types, and farmers' tradition. According to (Subedi, 2001), the following cropping systems can be found in the hills of Nepal:

Sole cropping: Maize or millet are grown sole in low hills (<1000m) where crop duration of maize is shorter and millet can be planted after maize harvest. The area was growing in relay system in not possible, maize is grown in khet land and millet is direct seeded (Subedi, 1990 and Sthapit *et al.*, 1990).

Maize/millet relay cropping: A perfect maize/millet relay cropping system is practiced at and above 1000m altitude and upto 1800m (Subedi *et al*., 1991) but occasionally, it can be observed at 500m-1000m.

Sequential cropping: This is a scientific system developed and adopted by farmers to adjust two crops to a limited growing season and conditions. Within an altitude range, adjustments are made in planting time, depending on land type and growing conditions.

The common maize varieties grown with finger millet are kakani yellow, Arun-2, Ganesh-2 and Manakamana-1. The local varieties of maize are also used for cultivation. The common finger millet varieties are different locals, with Okhale-1 and NE-6401-26 as improved varieties.

According to Khadka *et al*., (2014), the yield of direct seeded finger millet in line as relay crop with maize was compared with the traditional method of transplanting of finger millet as a relay crop with maize(n=15). The yield difference is shown below in Table 2. Direct seeding method of finger millet was found appropriate in mono cropping conditions but not in relay cropping with maize. The yield was found higher in transplanted finger millet as relay crop with maize in comparison to direct seeded method.

Table 2. Yield comparison of direct seeded and transplanted finger millet with maize.

S.N.	Treatment/Practice	Mean Yield	Test Statistics
1	Direct seeded finger millet in line as relay crop with maize	665.4	T=-10.26 on 14 d.f; Probability < 0.001
2	Transplanted finger millet in traditional method as relay crop with maize	2110.3	

Source: Khadka *et al.,* (2014).

Prospects of maize-millet intercropping

When two crops are planted in a same land area at a same time, obviously, there will be efficient and economic use of space, time and labor. Maize and millet are labor intensive farming and this system of cropping can be beneficial for farmers to utilize their land and labor economically. If the factors such as climatic condition, crop used, and planting time are right then the relay cropping is successful (Joseph *et al*., 2018). The prospects of maize-millet intercropping are discussed below:

Increase in productivity: One of the main reasons for the use of relay cropping around the world is that it produces more than a pure cropping of same land amount (Caballero and Goicoechea, 1995). Maize and Millet do not compete for the available resources and due to this, yield and productivity is increased. This system of cropping can be used to popularize maize cultivation in non-traditional maize growing areas (Pandey *et al*., 2001).

Efficient utilization of resources: This cropping system improves the use of limited resources (Dapaah *et al*., 2003). Due to the differential utilization of environmental resources between the main crop and the intercrop, the resources are used more effectively than a pure cropping with a resultant increasing yield (Jensen, 1996). Moreover, two crops differing in height, canopy, adaptation and growth habits grow simultaneously with least competition (Bhatti *et al*., 2006), greater yield stability over different seasons and better use of land resources.

Minimize disease, pest and weed incidence: The component crops utilized in intercropping systems differ in morphology, growth and adaptation, growing simultaneously with a resultant possibility of better smothering effect on weeds and control over pests and diseases (Chu *et al*., 2004). This cropping provides increased diversity, which facilitates better biological control of pests (Stephen, 2009). The cultivated crops cover the ground which ultimately suppresses the weed growth in the field.

Insurance against failure of crops: Intercropping gives a potential opportunity to increase profitability with low fixed cost for land as a result of second crop in same field (Thobatsi, 2009). And if, the crop production is negatively affected then it acts as an insurance against inclement weather. If maize growth is poor by any reason, then at least the good performance of millet compensates the overall yield and vice-versa (Subedi, 2001).

Constraints of maize-millet intercropping

Although, the relay cropping system of maize and millet farming has shown to be more productive, there are still many limitations which are identified. The productivity of maize and millet are below their potentials. The observed constraints affecting the productivity of the crops are as follows:

Maize and Millet competition: Various field experiments confirm that the competition within the crops exists in intercropping of crops. Mostly, millet production was found suppressed by maize but it depends on the length of overlapping period (Subedi, 2001). Improved maize varieties have a high nutrient demand resulting in poor millet yield. Improved varieties of finger millet which perform well in sole cropping tend to perform poorly under relay system (Sthapit *et al*., 1991). Based on the study performed by (Karki *et al*., 2014), the yield will be reduced if the field is not thinned until 60 DAS. Maize population density significantly influences the yield and any deviation from this density results in decreased yield.

Lack of suitable improved varieties: Adaptation of finger millet is an additional problem in varietal diversification. The improved variety of finger millet, Okhale-1 is not suitable in higher elevation. To reduce competition among crops, finger millet should be planted late which may result in cold induced sterility. Cold tolerant millet varieties need to be developed to get optimum yield. Also, there is no variety of maize which is specially recommended for maize/millet system. Farmers do not consciously select the variety and the varietal contamination can be a serious problem (Subedi, 2001).

Highly labor intensive system: Both maize and millet are labor intensive crops. Transplanting of millet and weeding of maize and millet is the most labor intensive operation. Although the area of finger millet is reported to be increasing, the area of finger millet in high altitude is declining in favor of less labor intensive crops. Because of this and food preference, this system is under threat to be replaced by other crops such as vegetables, legumes, etc (Subedi, 2001).

Soil and Nutrient loss: Soil fertility of maize based farming in Nepal is gradually declining (Subedi *et al*., 1991 and Rajbhandari, 2000). Finger millet is almost grown on residual nutrients applied to maize so, regardless of the quantity of manure applied, it is of poor quality. Both crops being cereal and having same root system, it seems nutrient exhaustive, depleting available nutrients from the soil. From the study of (Shakya *et al*., 1991), farmers indicated that the declining fertility of soil as a factor constraining millet yields. According to (Khadka, 1990), it is quite possible that they may be draining the nutrients from soil more rapidly than any other cropping patterns.

Conclusion

Maize and Finger millet are the major food crops for the people of hill area. According to the variation of the altitude and land type, the system of cropping can be either mono cropped or intercropped. The relay cropping of maize and finger millet is a common practice in the hills of Nepal. The cropping of finger millet under maize can be done either directly seeded or transplanted. Despite the fact that these both crops are widely cultivated and have great importance to the people living in hilly location, the study regarding these crops is very few. This cropping system has been used from ages ago in hills but there is not much documentation available of the research and findings on these crops. This paper has mainly focused to reveal the cropping system, prospects and constraints of intercropping in hills by studying the very few available records. This cropping system can be very profitable if the required considerations are fulfilled, prospects focused and constraints reduced. Finger millet, even being the major crops in hill areas are generally neglected to be studied. Apart from this, soil fertility constraints, suitable varieties and plant protection research should be strengthened. Specifically, it can be concluded that, maize-millet intercropping system can boost yield by utilizing the available resources and also, the incidence of weeds and insect pest can be reduced in this system of cropping. The major advantage of intercropping system is that it can act as an insurance against crop failure. But, to extract the optimum potential of both the crops, the existing challenges of this cropping system should be thoroughly studied and approaches should be developed and disseminated to minimize the limitations so that the farmers can achieve the best from the system.

Recommendation

For the sustainability of maize and finger millet intercropping system, reaching its potential, the identified issues should be addressed so that, it can turn out to be a profitable and beneficial cropping, not only for the hills of Nepal but to the whole nation. According to the facts and findings, to uplift the productivity by minimizing the soil loss, the following efforts should be made by the farmers as well as concerned authorities:

- The suitable varieties of maize and millet should be selected for intercropping condition so that, the yield of both crops reach its potential. For this, the suitable varieties are to be developed and disseminated to the farmers.
- Maintenance of appropriate plant density of maize is essential to gain optimum yield from the system.
- Imbalance use of chemical fertilizers should be discouraged. IPNM based farming system should be developed.
- Studies on labor use of the system are necessary.
- The loss of soil fertility and nutrients should be minimized for the long run of the cropping.
- The plant protection research should be strengthened to minimize insect pest incidence.
- For the adaptation of required materials at different altitude, evaluation should be made on best local materials to reduce the problems of adaptability in the localized area.
- Planting method, planting time and planting area should be chosen wisely to enhance the potential of both the crops.

Figure 2. *Showing maize and finger millet intercropped in field.*

Open Access: This is an open access article distributed under the terms of the Creative Commons Attribution NonCommercial 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author(s) or sources are credited.

REFERENCES

Acharya, G. P., Tripathi, B. P., Shrestha, S. P., & Gregory, P. J. (2001). Nutrients management in maize-finger millet system in the hills of Nepal. In: Hill crops workshop proceedings of summer and winter crops workshop finger millet, buckwheat and barley. March, 27-29, 2000, Lumle Kaski and September 12-14, 2000, Parwanipur, Bara, Nepal Agriculture Research council (NARC), Khumaltar.

Bhatti, I. H., Ahmad, R., Jabbar, A., Nazir, M. S., & Mahmood T. (2006). Competitive behavior of component crops in different sesame-legume intercropping systems. *International Journal of Agriculture and Biology*, *8* (2), 165–167.

Caballero, R., & Goicoechea, E. L. (1995). Forage yield quality of common vetch and oat sown varying seeding ratios and seeding rates of vetch. *Field Crops Research*, *41*, 135-140.

Chu, G. X., Shen, Q. R., & Cao, J. L. (2004). Nitrogen fixation and N transfer from peanut to rice cultivated in aerobic soil in intercropping system and its effect on soil N-fertility. *Plant and Soil*, 263, 17–27.

Dapaah, H. K., Asafu-Agyei, J. N., Ennin, S. A., & Yamoah, C. Y. (2003). Yield stability of cassava, maize, soybean and cowpea intercrops. *Journal of Agricultural Science Cambridge, 140*, 73–82.

Gairhe, S., Gauchan, D., & Timsina, K.P. (2021). Prospect and potentiality of finger millet in Nepal: Nutritional security and trade perspective. *Journal of Agriculture and Natural Resources*, *4*(2), 63-74.

Jensen, E. S. (1996). Grain yield, symbiotic N2 Fixation and interspecific competition for inorganic N in pea-barley intercrops. *Plant and Soil, 182*, 25–38.

Joseph, K. X., Yaro, R. N., Soyel, J. K., Kofi, E. S. and Ghaney, P. (2018). Role of Intercropping in Modern Agriculture and Sustainability: A Review. *British Journal of Science.*

Karki, T. B., Sah, S. K., Thapa, R. B., McDonald, A. J., & Davis, A. S. (2014). Plant Density Affects the Productivity of Maize / Finger millet Systems in the Mid Hills of Nepal. *Research and Reviews: Journal of Agriculture and Allied Sciences.*

Khadka, K., Shrestha, A., & Chaudhary, P. (2014). Improved Agronomy: Option for raising the interest of finger millet farmers in Nepal. *Presented at the International Food Security Dialogue 2014 "Enhancing Food Production, Gender Equity and Nutritional Security in a Changing World."*

Khadka, R. J. (1990). Finger millet production. Household Importance and Research at Pakhribas Agricultural Center. Paper presented in Millet based Workshop Organized by NHCIP in Kathmandu on 11-12, Oct 1990.

Maitra Sagar, Tanmoy Shankar and Pradipta Banerjee (2020). Potential and Advantage of Maize-Legume Intercropping System. https://www.intechopen.com/chapters/71463

MOAC, Statistical Information on Nepalese Agriculture (2075/76). Ministry of Agriculture, Land Management and Cooperatives, Kathmandu. 2019.

Panda, S. C. (2010). Agronomy (pp. 99–137). Jodhpur, India: Agrobios (India).

Pandey, A. K., Singh, N. N., & Gupta, H. S. (2001). In: N.P. Rajbhandari, J.K. Ransom, K. Adhikari and A.F.E. Palmer (2001). Sustainable maize production systems for Nepal: Proceedings of a maize symposium held, December 3-5, 2001, Kathmandu, Nepal, NARC and CIMMYT.

Paudel, B. K, S. B., M. N., Shah, U. S., Gurung, D. B., Sharma, D. R., & KC, G. (2001). Finger millet varietal investigation report for mid hill of Nepal. In: Hill crops workshop proceedings of summer and winter crops workshop Finger millet, Buckwheat and Barley. March, 27-29, 2000, Lumlekaski and September 12-14, 2000, Parwanipur, Bara, Nepal Agriculture Research council (NARC), Khumaltar.

Paudel, M. N (2016). Multiple cropping for Raising Productivity and Farm Income of Small Farmers. *Journal of Nepal Agricultural Research Council*, *2*, 37-45.

Paudyal, K. R., Ransom, J. K., Rajbhandari, N. P., Adhikari, K., Gerpacio, R. V., & Pingali, P. L. (2001). Maize in Nepal: Production Systems, Constraints, and Priorities for Research. Kathmandu: NARC and CIMMYT.

Rajbhandari, N. P. (2000). Declining soil fertility constraints to maize production in the hills- a review of recent surveys of farmer practices, perception and conceptualizing basis for proper targeting of maize research in the hills. pp. 10-20. In B.P. Tripathi, N.P. Rajbhandari, and J.K. Ransom (Editors) Improved Soil Fertility Management for sustaining maize production. Proceedings of a Working Group Meeting of Hill Maize Research Project, 16-18 August, 2000, Lumle, Nepal.

Shakya, P. B., Upreti, R. P., & Vaidy, S. (1991). Finger millet in Nepal: Importance, Utilization and Farming system in a socio-economic context. National Hill Crops Research Program supported by IDRC.

Shrestha, R.K. Agroecosystem of the Mid-hills.

Shrestha, S. P., Tripathi, B. P., & Acharya, G. P. (2001). Maize/ finger-millet system in the marginal Bari lands of Western hills of Nepal. In: Hill crops workshop proceedings of summer and winter crops workshop finger millet, buckwheat and barley. March, 27-29, 2000, Lumlekaski and September 12-14, 2000, Parwanipur, Bara, Nepal Agriculture Research council (NARC), Khumaltar.

Stephen Machado (2009). Does intercropping have a role in modern agriculture? Journal of soil and water conservation. vol. 64, no. 2. Pp 55A-57A.

Sthapit, B. R. & Subedi, M. (1990). Finger Millet Production system in the mid hills of Lumle Area: Its Household Importance, Constraint and Research Need. Technical paper no 3, Lumle Agricultural Center, Nepal. Paper presented in the millet workshop organized by NHCIP in Kathmandu on 11-12, Oct.1990.

Sthapit, B. R., Pradhanang, P. M., Khadka, R. J., & Subedi K. D (1991). Maize and finger millet relay intercropping system in the hills of Nepal: Its constraints, research findings and prospects.

Subedi, K. D. (1990). Study of maize/finger millet relay intercropping in the hills of Nepal: measures for production maximization. MSc Thesis, University of Reading, UK.

Subedi, K. D. (2001). Maize and finger millet relay inter cropping system in the hills of Nepal: Issues for sustainability. In: N P Rajbhandari, J K Ransom, K Adhikari and AFE Palmer (2001). Sustainable maize production systems for Nepal: Proceedings of a maize symposium held, December 3-5, 2001, Kathmandu, Nepal, NARC and CIMMYT.

Thobatsi, T. (2009). Growth and Yield Responses of Maize (Zea mays L.) and Cowpea (Vigna unguiculata L.) in an Intercropping System. MSc. (Agri.) Thesis, Pretoria University

Upreti, R. P. (2001a). Conservation and utilization of genetic resources of Finger millet in Nepal: Status, Problem and Future prospects. A country report presented in a project design workshop on "Enhancing the contribution of neglected and underutilized species to food security and income to the rural poor" at MSSFRF, Chennai (India) From January 23-25, 2001. Published in: Hill crops workshop proceedings of summer and winter crop workshop finger-millet, buckwheat and Barley. Hill crops research program, Kavre, Dolakha, NARC, Khumaltar, 2001

Yamoah, C. F., Bationo, A., Shapiro, B., & Koala, S. (2003). Soil Management Practices to Improve Nutrient-use Efficiencies and Reduce Risk in Millet-based Cropping Systems in the Sahel.