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Sweet potato varieties to diversify cultivars in Bhutan

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Abstract

Sweet potato (*Ipomea batatas* (L.) Lam) is an important root crop grown in the world. It provides carbohydrates, proteins, vitamins, fibre and essential minerals. With limited released varieties available, and the crop being undocumented thus far, sweet potato production in Bhutan is insignificant and has not gained scope in agricultural food systems. For nutrient and crop diversification, three improved varieties from Japan i.e., Beni Azumi (proposed name: Bajo Kewa ngam-I), Orange flesh (Proposed name: Bajo kewa-ngam-II), Gorojima and a local variety as a check were evaluated under three different agro-ecological zones to ascertain their performance in terms of yield and other yield attributes. The experiment was laid out in a Randomized Complete Block Design with four treatments each with three replications. The result showed no significant difference in yields between the varieties. Nonetheless, it was observed that orange flesh variety out-yielded (13.8 t/ac) all other experimented varieties across all experimental sites. The variety orange flesh followed by Beni Azumi and Gorojima were the most preferred variety based on their yield potential, pests and diseases tolerance, organoleptic test (taste, texture and colour) and yield attributes. All three varieties showed good yield stability.

Keywords: Agroecological zones, sweet potato, varieties, yields

Introduction

Sweet potato (*Ipomea batatas* (L.) Lam) is an important root crop grown throughout the world for starchy and nutritious tuberous roots. Originated from tropical America, as a hybrid cross (O'Brien, 1972), it is the third most important crop after rice and cassava (FAO, 2016) with a global annual production of 106 million tonnes from 8 million hectares (Abrham *et al*., 2021). Widely grown across the tropics and subtropics of Asia, Africa and the Pacific, it is one of the staple foods in some of the states of Africa with a recorded per capita consumption of 165 kg in a year (Loebenstein, 2003). Asia is the largest sweet potato producing continent with China accounting for 75% (Abrham *et al*., 2021). Sweet potato provides the highest starch amongst tuber crops (CIP, n.d.). It is a rich source of heat-stable vitamin C, vitamin E, B5, B6, fibres, polyphenols, calcium, magnesium, potassium and detox functional glycolipid "yarapin" (Tomiyasu, 2020) and colour-

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ful varieties like Orange fleshed contain more vitamin C, and beta carotene (Adenuga, 2010; Laurie, 2010; Šlosár *et al*., 2019), which addresses Vitamin-A deficiency. Sweet potato leaves are a good source of protein, fibres, carbohydrates, and minerals such as K, Ca, Mn, Cu and Fe, which are consumed for alleviating malnutrition in many developing countries (Sun *et al*., 2014). Dense in nutrients, sweet potato is an ideal food for diabetic patients, pregnant women and babies (Diaconu *et al*., 2017).

Easy and also being a hardy crop (Laurie, 2010), sweet potato can be grown with least care and attention (Abidin *et al*., 2017). Owing to this, sweet potato has a long history of being a life-saving crop and was also used for securing food and nutrition during the devastating famine of Japan and China in early 1960s, and Uganda in 1990s (CIP, n.d.).

Sweet potato has gained the least attention in Bhutan and as such had remained underexploited until today. Its production in 2019 from an area of 63 acres was 47 MT (MoAF, 2019). As a little-known crop, production and yield data and other related information are scant. Small-scale production is devoted mainly to self-consumption. As of 2021, there are no improved varieties registered with the Department of Agriculture (MoAF, 2019).

The traditional Bhutanese diet still dominantly constitutes carbohydrate-rich food such as rice, maize and potato (Tenzin *et al*., 2018) despite a manifold increase in vegetable production and its availability over the years. Owing to a deficiency of vitamins in their daily meals, peripheral neuropathy (Dzed *et al*., 2015) and glossitis (Gyeltshen *et al*., 2021) are highly prevalent amongst children in boarding schools. Thus, the promotion of sweet potato cultivation in the country would not only diversify maize and rice-based farming systems (Katwal, n.d.) but would also help diversify nutritional availability.

For crop and nutrition diversification, and to establish the varietal baseline information on sweet potatoes in the country, three potential sweet potato varieties were studied for their agronomic performance in different agroecological zones of the country. The study aimed at making available of the most suitable and potential variety for production in the country.

Materials and Method

Planting material

Three improved varieties of sweet potato were introduced from Japan during the Integrated Horticulture Promotion Project period (2015-2021). One local variety was used as a check variety.

Location and period

Three experimental sites were selected for the study. Identified sites varied from 650-2400 meters above sea level (m.a.s.l.). The researcher-managed trial was carried out at the Agriculture Research Development Centre (ARDC), Bajo, for two consecutive years (2019-2020). In 2020, in parallel, sweet potato trials were set up in farmers' fields in three agroecological zones (low, mid and high; Table 1) and were managed by farmers themselves following their production management practices. Three farmers, each from low, mid and high altitude agroecological zones were identified for setting up the trials.

Treatments and experimental designs

The treatment consisted of three improved varieties from Japan – Beni Azumi (proposed name: Bajo Kewa ngam-I), Orange flesh (Proposed name: Bajo kewa-ngam-II), Gorojima, and a local variety. The experiment was laid out in a Randomized Complete Block Design with four varieties, each with three replications. Each replication plot was 0.5 x 6 m and the whole experimental plot in each site was 45 m^2.

Experimental procedures and field management

After land preparation, Suphala (15N:15P:15K) was applied as a basal dose

@100 kg/acre (Tomiyasu, 2020). Uniform vine (stem) cuttings – each measuring 30 cm long and consisting of 5-7 nodes were prepared and planted in the researcher-managed field (ARDC Bajo) on 14 June 2019 and 15 June 2020. Similarly, stem cuttings in the farmer-managed fields in Thimphu (high AEZ) and Dagana (low AEZ) were planted on 15 April 2020 and 23 June 2020 respectively.

The vine/stem cuttings were planted by burying two-thirds of the cuttings inside the soil, and the upper one-third portion was exposed above the soil at 45° (Caribbean Agricultural Research and Development Institute [CARDI], 2010). The vine cuttings were spaced at 30 cm between plants (CARDI, 2010) and 50 cm between rows. Turning up of the vines, earthing up and all other agronomic practices were carried out as recommended by Tomiyasu (2020). On-farm trial plots were subjected to farmers' management practices except for the length of vine cuttings and planting space, which were maintained similar to the ones carried out at the research station.

Data collection and data analysis

Sweet potato tubers at ARDC Bajo and Dagana (farmer's field) were harvested after 120 days of planting in mid-October 2020 and those in Thimphu (farmer's field) were harvested in mid-November 2020. Yield and yield attributes such as individual tuber weight, length, diameter, and variety acceptance were recorded. Incidences of pests and diseases were also recorded. From every treatment, 10 plants each were sampled to check for pests and diseases at the time of harvest. The pest detection method was largely focused on *Cylas formicarius,* a major pest for sweet potatoes. Sweet potato weevil infestation was measured by vine and tuber infestation. Severity of pest infestation was measured by percent tuber damage while the incidence was measured by percent plant infested (Manandhar *et al*., 2016).

Analysis of variance was performed at each location to assess the differences in yield parameters of varieties. On-way ANOVA was performed for individual locations and years, followed by combined ANOVA to study the effects of different factors in different years and locations (Dafaallah, 2019). Normality test of residuals and homogeneity test of the variance were done using Shapiro-Wilk and Bartlett's test respectively. Post-hoc comparison using Duncan test was performed wherever a treatment effect was found significant at $p < 0.05$.

Varietal preferences by consumers based on taste, flavour, and colour were ranked from 1-4 (where 4 = very good, 3 = moderate, 2 = good, 1 = not good) as done by Vindras *et al*. (n.d.).

Table 1: Experimental sites

Location	Geographical coordinates	Dzongkhag	GPS Altitude (m.a.s.l)	Agro-ecological zone
Tsendagang	89.97814, 26.94798	Dagana	650	Low
ARDC Bajo	89.900329, 27.491731	Wangdue	1210	Mid
Thimphu	89.635714, 27.501222	Thimphu	2340	High

Results and Discussion

A. Agronomic traits

On-farm yield potential

For the on-farm experimental plots, Analysis of Variance revealed that there were no significant yield differences among the varieties (*p*

> 0.05, Table 3). At Dagana (650 m.a.s.l), no significant (p = 0.1) yield differences were observed among the varieties. Nonetheless, the orange flesh variety (Bajo kewa ngam-II) recorded the highest mean yield of 13.4 t/ac, followed by Beni Azumi (Bajo kewa ngam-I) and Gorojima at average yields of 10.4 t/ac and 9.7 t/ac respectively. Varieties evaluated at Thimphu (2340 m.a.s.l) recorded significant yield differences (p = 0.008) among the treatments.

Orange flesh significantly produced the highest mean yield of 6.9 t/ac among the treatments. Local Pink recorded the lowest mean yield of 4.9 t/ac among the evaluated varieties. Orange flesh variety also out-yielded all other varieties at both the on-farm sites (Figure 1).

On-station yield potential and yield stability

There was no significant (p = 0.08) differences observed between the mean yields of varieties evaluated at the on-station experiment. During the two years evaluation period, orange flesh out-yielded all other varieties with a mean yield of 13 t/ac in 2020 and 12.7 t/ac in 2021 respectively. Local Pink recorded the lowest mean yield of 9.8 t/ac and 9.1 t/ac in 2020 and 2021 respectively.

There was no significant difference ($p \geq 0.05$) observed in the yield of the varieties by years. However, significant differences ($p < 0.05$) in the mean yield of the varieties with regard to locations were observed. Similar finding is reported by Belehu (2003) and justified that the outcome could be due to the influence of abiotic factors prevalent in each location. Rich and heavy soil results in higher yield but low-quality roots, whereas extremely poor and light soil yields less but good quality roots (Brandenberger *et al.*, 2017). Sweet potatoes grow well across altitudes ranging from sea level to 2500 m.a.s.l (Ngeve *et al.*, 1994). Our study showed that sweet potato yielded more at lower altitudes compared to higher elevations (Figure 1) with a minimum yield at Thimphu (2340 m.a.s.l). However, as reported by Ngeve *et al.* (1994) the yield remained same at Wangdue and Dagana. This could be due to poor awareness and lack of access to production guides which could impact production skills and thus indirectly affect the production (Jepkemboi *et al.,* 2016). However, our study did not assess this gap.

Table 2: On-station yield potential of sweet potato cultivars

	Yield (t/ac) in different years	
Variety	**2020**	**2019**
Beni Azuma(BK-1)	10.5	9.9
Orange Flesh(BK-2	13.8	12.7
Gorojima	10	9.3
Local Pink	9.8	9
Mean	7.4	10.3
CV(%)	14	23
P value	0.08	0.3

Yield attributes

Yield attributes such as tuber count, tuber weight, tuber length, and tuber diameter were measured. Analysis of Variance showed that there was a significant difference between the treatments on tuber weight (p = 0.03), tuber length (p = 0.02) and the number of tubers formed on a plant (p = 0.006). However, no significant differences in tuber diameter were recorded between the treatments (p = 0.14). Orange Flesh had a significantly higher number of tubers per plant (10) followed by Gorojima (7) whilst the Local Pink variety had the least (6). Statistically longest mean root length of 21 cm, and highest mean tuber weight of 277 g was recorded in the Local Pink variety.

Days to maturity

There was no significant difference ($p \geq 0.05$) in the days taken to harvesting between the treatments. All experimental varieties were harvested on 120 days after planting of vine

Table 3: Combined ANOVA for different years for on-station experiment

SOV	SS	*df*	MS	F-cal	P-value
Replication	11.14	2	5.57	1.15	0.345
Year	20.42	1	20.42	4.21	0.059
Treatment	46.08	3	15.36	3.17	0.057
Year*Treatment	20.06	3	6.69	1.38	0.289
Error pooled	67.87	14	4.84		
Total	165.57	23			

Table 4: Combined ANOVA yields at different locations

SOV	SS	*df*	MS	F-cal	P-value
Replication	0.55	2	0.274	0.064	0.93
Location	343.49	2	171.74	40.26	4.4e-08
Treatment	47.49	3	15.83	3.71	0.026
Location*Treatment	38.28	6	6.38	1.49	0.225
Error pooled	58.72	22	4.27		
Total	523.76	35			

cuttings. Tubers were harvested when the sweet potato roots attended the marketable stage (CARDI, 2010).

Degree Brix content

The total soluble solids (TSS) in uncooked sweet potato significantly varied (p = 0.001) among the varieties (Table 6). Analysis of Variance showed the highest TSS content in Beni Azumi (Bajo kewa ngam-I), followed by Gorojima, Orange Flesh (Bajo Kewa ngam-2), and Local Pink. Nonetheless, ANOVA did not show significant difference (p = 0.1) in TSS content between varieties after cooking. In absolute terms, Beni Azumi (Bajo kewa ngam -I) showed the highest mean TSS content of

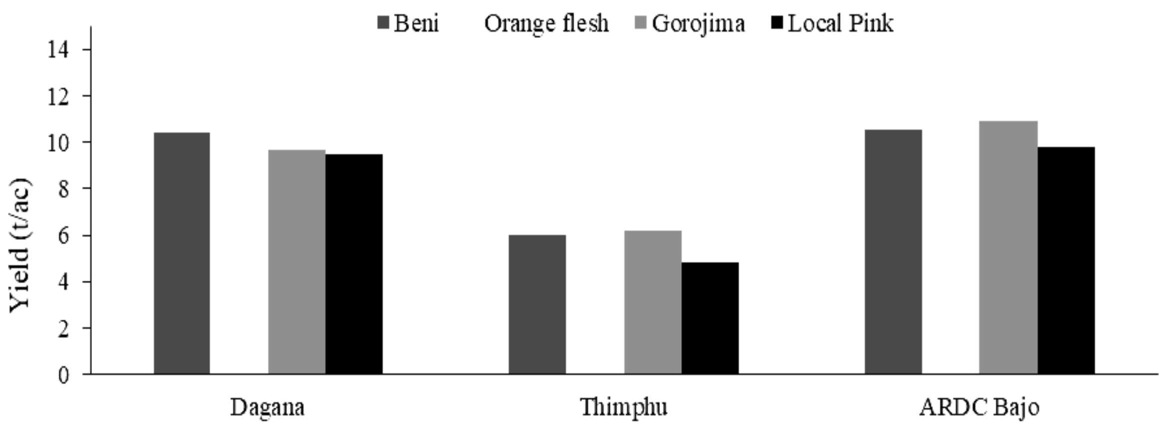

Figure 1: The manuscript did not have the figure number and the figure label

22.13° Brix and 11.13° Brix respectively after cooking and precooking time. The Local Pink had the least average TSS at 19.1° Brix. and 8.7° Brix respectively at the cooked and pre-cooked stage.

B. Preferences

Orange flesh (Bajo kewa ngam-II) was the highest preferred variety (Table 7). Assessors accorded the highest scale of 4 (1-4 scale) in flavour, buttery texture and the colour of Orange flesh variety. Based on sweetness, Beni Azumi was assessed as a highly preferred variety followed by orange flesh and Gorojima. Local Pink had the lowest rank for varietal preference with the lowest scale of 1 in flavour, texture, flesh colour and sweetness.

C. Pest incidences and management

No major disease incidence was found affecting sweet potato plants during the evaluation period from 2019-2020. However, we have observed sweet potato weevil (*Cylas formicarius*.) infestation, which is one of the most serious and destructive pests (Ames *et al*., 1997; Cockerham *et al*., 1954). It was observed that the experimental plot at ARDC Bajo (on-station) had comparatively the highest weevil incidences in all the varieties (Figure 2). At the ARDC Bajo experimental site (1210 m.a.s.l), *Cylas formicarius* incidence of 40% with a severity of 3 was recorded for Gorojima. It was followed by Beni Azumi and Local Pink with a 30% incidence and severity of 1(1-4 scale). Orange flesh variety recorded only 10% pest incidence with a severity of 1. Similarly, on-farm plots in Thimphu (2430 m.a.s.l) saw minimal incidence (0.04%) in the Gorojima variety while Dagana (659 m.a.s.l) did not record any weevil incidences.

Similar findings were also reported in Uganda wherein *Cylas* spp. incidence was recorded only up to 2400 m.a.s.l. (Okonya and Kroschel, 2013). It was reported that in Uganda, the highest rate (77%) of *Cylas* spp. incidence was at low altitude zones (1422-1814 m.a.s.l) and lowest rate (23%) of *Cylas* spp. incidences was at high altitude zones (1992-2438 m.a.s.l). The incidence of *Cylas* spp. also differs with factors such as types of planting material used, planting time, types of varieties used, and use of different integrated pest management practices (Ames *et al*., 1997).

Morphological characteristics

Beni Azumi (Bajor Kewa ngam-I) with dark pink roots and cream-coloured flesh has semi-erect vine with a mean vine length of 80.25 cm and green cordate leaves with short internodes. Orange flesh (Bajo Kewa Ngam-II) has a spreading vine with a recorded mean vine length of 161 cm and bears purple-coloured young leaves, while the mature leaves are cordate and green. It bears whitish-pink tubers with orange-coloured secondary flesh covering most of the flesh. Similarly, Gorojima has

Table 5: Varietal yield attributes from ARDC Bajo experimental site

Variety	Tuber No/Plant	Tuber weight (g)	Tuber length(cm)	Tuber Diameter (cm)	Flesh color
Beni Azumi	6.36b	219.49b	15.3b	52.19	White
Orange Flesh	10.21a	222.71b	15.98b	51.63	Orange
Gorojima	6.91b	221.39b	19.29b	47.23	White
Local Pink	5.67b	277.56a	21.63a	50.38	White
Mean	7.36	242.25	18.42	50.45	

Table 6: Total soluble solute of varieties from ARDC Bajo experimental site

Variety	Precooked (° Brix)	Cooked (° Brix)
Beni Azumi	11.1	22.1
Orange flesh	9	20.8
Gorojima	9.1	21.5
Local Pink	8.7	19.1
Mean	9.4	20.8
CV	1.6	5.78
P value	0	0.1

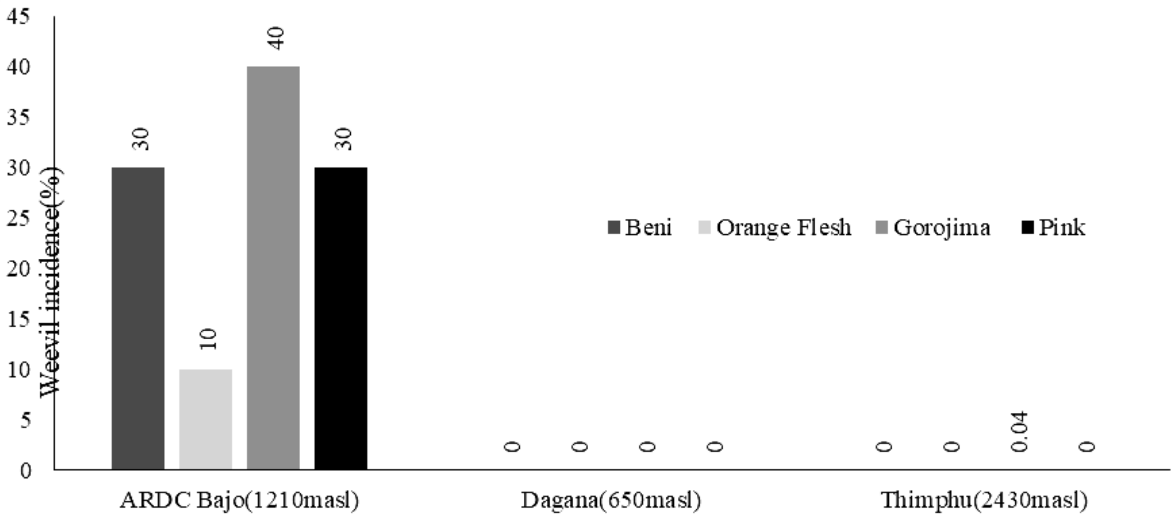

Figure 2: *Cylas formicarius* incidence at different sites (axis label needs changes?)

semi-erect vine with a mean vine length of 135 cm with short internodes. It has cordate shaped green-coloured leaves has light pink roots with white flesh. Local Pink has spreading type of vine with a mean vine length of 191 cm with long internodes. It bears cordate green leaves and dark pink roots having white flesh.

Conclusion

Orange flesh (Bajo Kewa ngam-II) was the highest preferred variety based on its taste, texture, and colour. Orange flesh variety also outyielded all other evaluated varieties across all the experimental sites with a mean yield of 12.7-13 t/ac. It also showed the lowest pest and disease incidences of 10% among the evaluated varieties. Beni Azumi (Bajo kewa ngam-I) and Gorojima were accorded second and third rank in varietal preference. These varieties closely followed orange flesh with a mean yield of 9.9-10.5 t/ac and 9.3-10 t/ac respectively. These varieties showed moderate (30%) pest incidences. Beni Azumi and Orange flesh were registered with the Department of Agriculture, Ministry of Agriculture and Forests of Bhutan in May 2021 as Bajo kewa ngam-I and Bajo kewa ngam-II. With the introduction of these cultivars, sweet potato cultivars in the country are diversified adding to the nutritional diversification.

References

Abidin, P.E., Carey, E., Mallubhotla, S., and Sones, K. (2017). *Sweetpotato cropping guide. In Africa Soil Health Consortium,* Nairobi.

Abrham, T., Beshir, H.M., and Haile, A. (2021). Sweet potato production practices, constraints, and variety evaluation under different storage types. *Food and Energy Security*, 10(1): 1–12. https://doi.org/10.1002/fes3.263

Adenuga, W. (2010). Nutritional and sensory profiles of sweet potato based infant weaning food fortified with cowpea and peanut. *Journal of Food Technology* , 8(5): 223–228.

Ames, T., Smit, N.E.J.M., Braun, A.R., and Skoglund, L. G. (1997). *Sweetpotato : Major pests, diseases, and nutritional disorders.* ??? This reference seems incomplete with pages and other details

Belehu, T. (2003). *Agronomical and physiological factors affecting growth, development and yield.* University of Pretoria, Doctor of Philosophy, Thesis, 223.

Brandenberger, L., Shrefler, J., Rebek, E., and Damicone, J. (2017). *Sweet potato production*.

CARDI. (2010). *Sweet potato technical manual*. In The Caribbean Agricultural Research and Development Institute.

CIP. (n.d.). International Potato Center. International Potato Center. ??? This reference seems incomplete with pages and other details

Cockerham, K.L., Deen, O.T., Christian, M.B., and Newsom, L.D. (1954). *The biology of the sweet potato weevil*. Louisiana Agricultural Experiment Station Technical Bulletin, 483, 1–30.

Dafaallah, A.B. (2019). *Combine analysis of variance* (pp. 1–29).

Diaconu, A., Draghici, R., Croitoru, M., Darghici, L., Cotet, G., and Paaschiv, A. (2017). Influence of the planting time in field on the tubers production obtained from sweet potato varities under the conditions of sandy soils. ??? This reference seems incomplete with pages and other details

Dzed, L., Dorji, T., Dhakal, G.P., Yangchen, P., and Wangmo, K. (2015). Status of Thiamin deficiency in boarding school children from seven districts in Bhutan with previous history of peripheral neuropathy outbreaks: a cohort study. *Bhutan Health Journal*, 1(1): 49–56. https://doi.org/10.47811/bhj.08

Gyeltshen, T., Dorji, L., Dorj, L., and Choden, K. (2021). Outbreak of oral ulcers (glossitis) among the students of three central schools under Tsirang district Bhutan, 2018. *BMC Oral Health*, 21(1): 1–7. https://doi.org/10.1186/s12903-021-01808-5

Jepkemboi, C., Kebeney, S.J., and Kitilit, J. (2016). Factors affecting sweet potato production and soil fertility challenges among smallholder farmers in Kenya. *RUFORUM Working Document Series*, 14(2): 695–705.

Katwal, T. (2013). Multiple cropping in Bhutanese agriculture: Present status and opportunities. In *Regional Consultative Meeting on Popularizing Multiple Cropping Innovations as a Means to Raise Productivity and Farm Income in SAARC Countries*. Peradeniya, Kandy Srilanka.

Laurie, S.M. (2010). *Agronomic performance, consumer acceptability and nutrient content of new sweet potato varieties in South Africa* (Doctoral dissertation, University of the Free State).

Loebenstein S., Fuentes J., Cohen L.F., S. (2003). *Sweet Potato.* Virus and virus-like diseases of major crops in developing countries.??? This reference seems incomplete with pages and other details

Manandhar, H.K., Timila, R.D., Sharma, S., Joshi, S., Manandhar, S., Gurung, S.B., Sthapit, S., Palikhey, E., Pandey, A., Joshi, B., Manandhar, G., Gauchan, D., Jarvis, D.I., and Sthapit, B.R. (2016). A field guide for identification and scoring methods of diseases in the mountain crops of Nepal. In *Bioversity International.* ??? This reference seems incomplete with pages and other details

MoAF. (2019). *Ministry of Agriculture and Forests Inventory of Released and De-notified Crops in Bhutan (1988-2019).* September, 2017–2019.

Ngeve, J.M., Hahn, S.K. and Bouwkamp, J.C. (1992). Effects of altitude and environments on sweet potato yield in Cameroon. *Tropical agriculture*, 69(1).

O'BRIEN, P.J. (1972). The Sweet Potato: Its origin and dispersal . *American anthropologist*, 74(3): 342-365.

Okonya, J., and Kroschel, J. (2013). Incidence, abundance and damage by the sweet potato butterfly (Acraea acerata Hew. and the African sweet potato weevils (Cylas spp.) across an altitude gradient in Kabale district, Uganda. *International Journal of AgriScience*, 3, 814–824.

Šlosár, M., Hegedűsová, A., Hegedűs, O., Mezeyová, I., Farkaš, J. and Golian, M. (2019). The evaluation of selected qualitative parameters of sweet potato (Ipomoea batatas L.) in dependence on its cultivar. *Potravinarstvo*, *13*(1).

Sun, H., Mu, T., Xi, L., Zhang, M., and Chen, J. (2014). Sweet potato (Ipomoea batatas L.) leaves as nutritional and functional foods. *Food Chemistry*, 156, 380–389. https://doi.org/10.1016/j.foodchem.2014.01.079

Tenzin, K., Lhadon, K., Phuntsho, L. and Lhadon, Y. (2018). Phenotypic characterization of common bean landraces from Eastern Bhutan and their potential use. 1(1), 125–132. ??? This reference seems incomplete with pages and other details

Tomiyasu (2020). Guide book on vegetable cultivation. ??? This reference seems incomplete with pages and other details

Vindras, C., Sinior, N., Howlett, S., Rey, F. and Taupier-letage, B. (2008). Tasting guide: Tools to integrate organoleptic quality criteria. ??? This reference seems incomplete with pages and other details