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Research paper

Evaluation of forage pea (*Pisum sativum* L.) genotypes in middle hill and Terai ecologies of Nepal

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Forage pea is a new crop for Nepali farming systems where searching for alternate winter forage legumes with better herbage and seed yield is one of the prioritized approaches to mitigate the severe nutrient deficit of the ruminants. In order to select the superior pea cultivar(s) for the promising and potential winter forage legume crop, the study was conducted for two consecutive years at three locations. The experiments were conducted at a location of middle hill (Lalitpur district) and at two locations of Terai (Banke and Sunsari districts). A total of five cultivars of pea (Banke local, Arkel, Journey, PRL88054-46 and PRL H3-2) were compared as the treatments for herbage and seed production. The experiments were executed in a Split-split plot design where pea cultivars were used in the Sub-sub-plots. The results of the study had revealed that the year effect, location effect and cultivar effect were significant. The cultivar Banke local at Banke district, Banke local, Journey and PRL H3-2 at Sunsari district and Banke local, PRL 88054-46 and PRL H3-2 at Lalitpur district had shown better herbage dry matter (DM) yield. Likewise, the Banke local had shown better seed yield at middle hill ecology whereas Banke local, Arkel and Journey were better for Terai ecology. The cultivar Banke local had produced better herbage as well as seed yield in middle hill and Terai ecologies.

Key words: *Cultivar, herbage dry matter, number of branches, plant height, seed yield*

INTRODUCTION

Feed shortage during the winter and spring seasons is one of the foremost reasons responsible for declined productivity of ruminants which is considered as a major shortcoming of the commercial ruminant farmers in Nepal (Singh and Singh, 2019). Crop byproducts, limited forages and tree leaves are the major sources of feeding ruminants during the winter season (Sharma, 2015). The inclusion of legume forages in ruminant diets during the dry and harsh winter is important to mitigate this differential span of the nutrient balance for the Nepalese ruminants. It necessitates the evaluation and screening of more winter forage legume crops that could produce better nutrient yield to the ruminants. Accordingly, a number of winter forage legumes are being introduced, tested and evaluated in different ecological regions of Nepal since several decades back (Singh & Singh, 2019; Ghimire, 2021). Even though, a limited number of legume forages are widely in practice during the winter season. Egyptian clover (*Trifolium alexandrinum* L.) and common vetch (*Vicia sativa* L.) are the examples of those conventional winter forage legumes predominantly being cultivated in Nepal for more than four decades, nevertheless, forage pea and grass pea are some of the alternate species getting the attention of the Nepalese farmers in recent years (Sharma, 2015). Due to its superior biomass potential with excellent forage quality, pea is becoming the popular alternative of conventional winter forage legume in the middle hills and Terai areas of Nepal (NAFQML, 2019).

Pea is among the four topmost important legume crops in the world. It has greater genetic diversities with winter and spring seasons cultivars which are classified as garden peas, field peas and forage peas. The forage peas are high biomass yielding with superior crude protein contents and are short-term crops (Fraser, Fychan, & Jones, 2001). Moreover, it is higher mineral and less fiber-containing than other cereal forages (Ellwood, 2004; Upreti & Shrestha, 2006). They are rapid-growing herbaceous legumes that have angular or roundish hollow stems covered by waxy bloom (Muehlbauer, 1997). The number of cultivars of forage pea are developed and are in use in different parts of the world (Heuze, Tran, & Giger-Reverdin, 2015; Luisetti, 2019). The older forage pea cultivars have long vines and normal leaf types with good biomass yield. But, newer ones produce as much or more biomass, are easier to manage and have better lodging resistance (Fleury, 2017). These modern cultivars are developed for higher protein content, better digestibility to animals and smaller sized seeds along with increased biomass yield (Fleury, 2017). Contradictory to this, several cultivars of field peas and garden peas (such as Banke local, Arkel) are being used for forage by the Nepali farmers due to scanty information about forage pea cultivars. Banke local is one of the conventional cultivars that is popularly growing in different parts of Nepal (PFD, 2017). This is a leafed cultivar with a dense leaf canopy. Arkel is the white- flowered exotic cultivar widely grown for the green pods in Nepal. It is a dwarf cultivar, but has vigorous growth yielding higher biomass (Agropedia, 2009). Journey is the modern cultivar of pea having very strong early seedling vigor and is one of the best spring forage cultivars. It is a small seed-sized cultivar that yields higher biomass at the flowering flat pod stage (ProGene, 2017). PRL88054-46 and PRL H3-2 are the typical forage pea cultivars with high biomass yields (Agropedia, 2009; PFD, 2017). PRL H3-2 is the fully-leafed late-maturing cultivar of the forage pea (Agropedia, 2009).

The herbage and seed yield of the pea cultivar is the sum of the genotype, environment and their interactions, and hence the choice of the right cultivar is an important tool to improve them in forage pea that depends on the local agro-climatic conditions. Therefore, the objectives of this study were to evaluate herbage yield and seed yield of different local and introduced cultivars and select them for the middle hills and Terai ecologies of Nepal.

MATERIALS AND METHODS

The evaluation of different pea cultivars for herbage biomass and seed yield was done for three locations (one middle hill site and two sites in Terai) for two winter seasons from October 2018 to June 2020. The experiments were conducted at the experimental sites of the National Pasture and Fodder Research Program, Khumaltar, Lalitpur for middle hill ecology. For the eastern and western Terai ecologies, the experimental sites of National Buffalo Research Program, Province-1, Tarahara, Sunsari and Directorate of Agricultural Research, Lumbini Province, Khajura, Banke were used for the experimentations. The experiments were laid out in the randomized arrangements in the field by executing split-split plot design. Year and location were used as main plot and sub-plot, respectively. A total of five pea cultivars, four improved/imported and one local cultivar (Banke local as the check), were used in the sub-sub plots in the experiments. Banke local and Arkel were collected from research stations under Nepal Agricultural Research Council and Journey, PRL88054-46 and PRL H3-2 were received from Lincoln University, New Zealand and Plant Research Limited, New Zealand. Each treatment was replicated four times in each location every year. The plot size for each experimental unit was 3×4 m^2. The seed rate was applied as 100 kg seeds ha^{-1} with 30 cm row to row spacing. The recommended dose of fertilizers was applied at the rate of 25:70:50 $N:P_2O_5:K_2O$ kg ha^{-1}. The irrigations were provided. The observations were taken on plant height and number of branches $plant^{-1}$, herbage biomass and seed yield during both of the years. Herbage DM was calculated by determining the moisture content of herbage in the laboratory of the National Animal Nutrition Research Center, Khumaltar, Lalitpur.

The data were analyzed by using the Statistical Tool for Agricultural Research 2.0.1 (STAR, 2014) for ANOVA and descriptive statistics. The temporal and location effects were partitioned by analyzing the data using the Split-split Plot Design with randomized blocks where year, location and cultivars were used as main plot, sub-plot and sub-sub plot. The significance of treatment, main effects and interaction effects were determined by F-test at 5%, 1% and 0.1% probability levels. The least significant difference at 5% ($LSD_{0.05}$) was used to separate means during multiple comparisons.

RESULTS AND DISCUSSION

Plant height and number of branches

The overall plant height was not affected ($p>0.05$) for different years, but affected ($p<0.001$) for the different locations and cultivars as the main effects during the combined analysis of both years' data. The interaction effect of year to location on plant height was also significant ($p<0.01$) resulting the difference on plant height at different locations over the years. Effect of location to cultivar interaction was significant on plant height having the tallest plant for Banke local in Banke district. The plant heights of the cultivars were differed significantly (p<0.001) in each location (Figure 1). In Lalitpur district, Banke local cultivar had the tallest (p<0.001) plants whereas Arkel and PRL88054-46 had attained shorter heights. Likely in Banke district, taller (p<0.001) plant height was obtained for the Banke local cultivar in comparison to Arkel and PRL 88054-46. Similar trends were found for Sunsari district too. Banke local cultivar had attained the tallest (p<0.001) plant height, which was followed by the PRL H3-2 and Journey. The cultivars Arkel and PRL88054-46 had lower (p<0.01) plant heights compared to other cultivars.

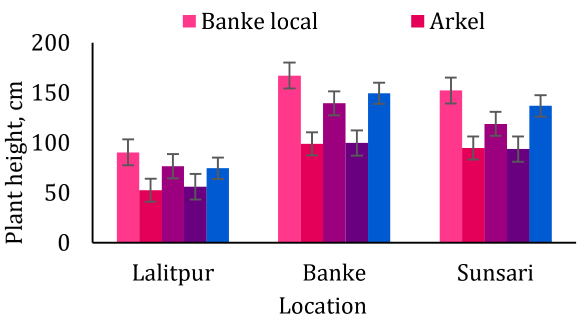

Figure 1. Plant height of different pea cultivars in different locations

The overall number of branches plant^{-1} was varied (p<0.001) during the first and second years. Similarly, it was significantly different (p<0.001) for the locations during the combined analysis of both years' data. The mixed results were obtained in the case of the number of branches plant^{-1} among different cultivars, although, Banke local cultivar had the highest (p<0.001) number of branches plant^{-1} in all the locations (Figure 2). In Lalitpur district, Arkel was observed as bearing the lowest (p<0.001) numbers of branches plant^{-1}. Similarly, Banke local cultivar was followed by PRL 88054-46 had higher (p<0.001) number of branches compared to Journey, PRL H 3-2 and Arkel in Banke district. In Sunsari district too, Arkel and Journey had the lowest (p<0.001) number of branches plant^{-1} in comparison to other cultivars.

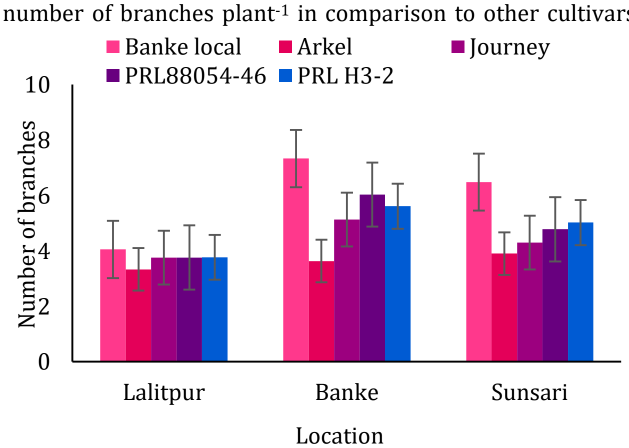

Figure 2. Number of branches plant^{-1} of different pea cultivars in different locations

Taller plant height and more number of branches are the indications of better adaptability of particular cultivar that is benefitted from prevailing climatic conditions in a specific location or region (Ishtiaq, Ahmad, & Shah, 1996; Khan, Ramzan, Jillani, & Mehmood, 2013). In the study, the forage pea genotypes had shown significant variation in plant height and number of branches plant^{-1}. The cultivar Banke local has shown consistently higher plant height and the number of branches plant^{-1} at all three locations. These responses to plant height could be due to the genetic characteristics of genotype and its adaptability to a particular environment as reported by Sharma, Chauhan and Jarial (2020). On the other hand, the Banke local is a late maturing-type cultivar that could be benefitted from the longer duration for attaining vegetative growth and from delayed reserve food materials diverted to sex expression which might have resulted the taller plant height. The cultivars Arkel and PRL 88054-46 had attained shorter plant heights in the study. This result of the lowest plant height of Arkel cultivar in middle hill ecology is also supported by the report of another study in Himanchal Pradesh of India. The author reported the minimum plant height for Arkel (51.16 cm) while comparing the nine pea cultivars (Sharma et al., 2020). The effect of genotype was significant to the number of branches of pea, but the effect of location was non-significant (Sharma et al., 2020). Contradictory to this, the number of branches of pea cultivars was higher (p<0.001) for the Terai ecology in comparison to the middle hill ecology in this study. The physiographic and climatic conditions of Terai ecology could be more suitable for the vegetative growth of these cultivars.

Herbage dry matter yield and seed yield

The effect of year was obtained significant (p<0.001) on the overall herbage DM yield of pea during the combined analysis of data. Similarly, the herbage DM yield was significantly varied for different locations (p<0.001). The overall herbage DM yield was higher for Terai ecology in which Banke district had the highest yield (p<0.001). The middle hills ecology (Lalitpur district) had yielded the lowest herbage DM. The herbage DM was variably obtained (p<0.001) for the locations over the years in their interaction. Similarly, the interaction of location and cultivar was obtained significant (p<0.001). But, the interaction effect of year and the cultivars was non-significant (Table 1).

Table 1. Table of significance for herbage dry matter and seed yield

Factors	Herbage dry matter yield	Seed yield
Year effect	<0.001	<0.001
Location effect	<0.001	<0.001
Cultivar effect	<0.001	<0.001
Year: Location	<0.001	<0.001
Location: Cultivar	<0.01	<0.001
Year: Cultivar	NS	<0.05

The effect of cultivar was significant (p<0.01) within all locations (Table 2). At Lalitpur district, Banke local, PRL88059 and PRL H3-2 cultivars had yielded higher herbage DM yield than other cultivars. But in Banke district, the Banke local cultivar produced higher herbage DM yield in comparison to

Table 2. Herbage DM and seed yield of different cultivars of peas in middle hills and Terai ecologies

Cultivars	Herbage dry matter yield, t ha^{-1}			Seed yield, t ha^{-1}		
	Lalitpur	Banke	Sunsari	Lalitpur	Banke	Sunsari
Banke local	6.660^{a}	11.091^{a}	6.925^{a}	1.576^{a}	2.424^{a}	1.193^{a}
Arkel	3.780^{c}	9.253^{b}	5.688^{b}	0.686^{c}	2.231^{a}	1.230^{a}
Journey	4.398^{bc}	9.543^{b}	6.325^{ab}	1.038^{b}	2.265^{a}	1.212^{a}
PRL88054-46	5.299^{ab}	9.239^{b}	5.762^{b}	1.047^{b}	2.001^{b}	1.125^{b}
PRL H3-2	5.557^{ab}	9.673^{b}	6.398^{ab}	-	-	-

Seed setting was not taken place for the cultivar PRL H3-2 in any location during the both of the years
Means in the same column with different superscripts are significantly different at 5% probability level

other cultivars. Similarly, Banke local cultivar had produced higher herbage DM yield, but was *et par* with Journey and PRL H3-2 in Sunsari district (Table 2).

Similarly, the highest ($p<0.001$) herbage DM yield was obtained for Banke local cultivar in Banke district than other treatment combinations. The cultivars Arkel and Journey in Lalitpur district of middle hill ecology had yielded lower ($p<0.001$) herbage DM yield compared to other cultivars (Table 2).The overall seed yield was different ($p<0.001$) between the two years. The location effect was also highly significant ($p<0.001$) resulting from the variation in seed yield among the locations. The interaction of year to location was highly significant ($p<0.001$). Likely, the interaction of location to cultivar effect was also highly significant ($p<0.001$). Similarly, the year to cultivar interaction effect was also significant at $p<0.05$ level (Table 1).

Similar to the herbage DM yield, the overall seed yield was also obtained higher ($p<0.001$) at Banke district in comparison to Sunsari and Lalitpur districts. In the case of seed yield too, the cultivars had shown significant differences ($p<0.001$) on the seed yield within each location. The Banke local cultivar had yielded the highest ($p<0.001$) and the cultivar Arkel had yielded the lowest ($p<0.001$) seed yield (0.686 t ha^{-1}) in Lalitpur district. The slightly divergent results were obtained in Banke district. The cultivars; Banke local, Journey and Arkel, had yielded statistically similar ($p<0.05$) seed yields, which were significantly higher ($p<0.001$) than PRL88054-46. Similar result was obtained in Sunsari district. Arkel, Journey and Banke local cultivars of pea had resulted statistically similar ($p>0.05$) seed yield which were higher ($p<0.001$) than PRL88054-46 cultivar (Table 2). Herbage DM and seed yield were higher for the Banke local, even though a couple of cultivars (PRL cultivars) in the study were typical high-yielding forage pea type. Banke local is an indeterminate type and leafed cultivar which had shown taller plant height along with more number of branches plant^{-1}. This could be the reason associated with the higher forage as well as seed yield of this cultivar compared to other improved and imported cultivars. Higher vigor, green area, photosynthate production and ground cover were attributed to the higher biomass for the indeterminate leafed cultivars in another study by Armstrong and Pate (1994). Although these parameters were not recorded in the present study, the taller plant height and more number of branches plant^{-1} had indicated the possibilities of higher vigor, green area, photosynthate production and ground cover in Banke local cultivar. Taller plant height, more number of branches plant^{-1} and higher herbage DM are direct positively and strongly correlated to the seed yield of pea (Togay, Togay, Yildirim, & Dogan, 2008) that may be the reason for higher seed yield in Banke local cultivar.

In the experiment, all the genotypes had shown better herbage DM yield, its components (plant height, number of branches plant^{-1}) and seed yield (except PRL H3-2) in Terai ecology than in middle hill ecology. Again, the higher herbage DM yield in Terai ecology could be attributed by the taller plant height and more number of branches plant^{-1} in these experiments. Improved herbage DM yield with its better components in Terai ecology due to the more favorable weather and soil conditions could have attributed to the higher seed yield. This reason is also further supported by the significant year effects and also year to location and year to genotype interaction effects in the study. The cultivars Arkel and Journey had also produced better seed yields which were *et par* with the Banke local cultivar in Terai ecology. This might have contributed to higher seed yield in Terai compared to hill ecology in this study.

Higher forage yield along with better seed productivity is the foremost desirable attribute considered for any forage species and cultivar (Ghimire, 2013). Although, Arkel and Journey had *et par* yield with Banke local in the Terai ecology (Banke and Sunsari locations), their significantly lower forage yield in these locations restraints them to be selected as the better genotypes. No seed settings of the PRL H3-2 at all the locations during both of the years had indicated that these ecological regions are not suitable for the seed production of PRL H3-2 cultivar during the winter season. High temperature, low humidity with hot air and heat stress at the time of flowering which prevails in the study sites could be the reason associated with these results. Although the PRL H3-2 cultivar had produced the better forage yield, failure of seed setting hinders to the promotion of this forage pea cultivar in these ecological regions.

The weather conditions during the growing season, locations and habitat quality, cultivar and the yielding ability of the particular cultivar in the specific location influences the seed and herbage yield of pea (Jeuffroy & Ney, 1997; Poggio, Satorre, Dethiou, & Gonzallo, 2005; Olle, 2017). The results of the present study were in line with this report. The year effects, location effects and cultivar effects were significant during the experiments. The interactions of year to location and to cultivar were also observed significant to the plant height, number of leaves, herbage DM and seed yield in the study. Likely, the significant differences among pea genotypes were found for herbage DM and seed yield over the years and in different locations. Sharma *et al.* (2020) also reported the considerable variations among the different genotypes (nine cultivars) and locations (600, 1375 and 1800 masl) on seed yield of the garden pea. The significant year and location effects and their interactions to genotypes had indicated the need for further study of these cultivars in other regions and in different seasons.

The ruminant farmers and also animal nutritionists are searching the alternate winter forage legume in order to mitigate the feed and nutrient (especially protein) deficit to ruminants in Nepal (NAFQML, 2019). Banke local, a cultivar of grain-legumes popularly grown by the Nepali farmers for seed, had shown better herbage as well as seed production potential among the cultivars evaluated during the study. Therefore, this cultivar may be one of the strong alternate winter forage legume crops in the middle hill and Terai ecologies of Nepal.

CONCLUSION

The results of the study revealed the Banke local was the best cultivar among the evaluated forage pea genotypes for the herbage dry matter yield in Banke district. Similarly, Banke local and Journey cultivars were better in Sunsari district. In middle hill ecology (Lalitpur district), Banke local and PRL88054-46 cultivars had produced higher herbage dry matter than other genotypes. From the perspective of seed production in Terai ecologies, Banke local, Arkel and Journey cultivars had better performance in comparison to others. Similarly, the cultivar Banke local had the highest seed yield in Lalitpur district, the middle hill ecology. Promotion of these better performing cultivars in different ecological regions and development of their package of practices could make substantial contributions in the production of winter forage legumes in the middle hills and Terai of Nepal. The significant variations on the herbage DM yield, its yield components and on the seed yield during different years and also at different locations had pointed out the need of further studies for other ecological regions and environmental conditions.

AUTHOR CONTRIBUTIONS

Ram Prasad Ghimire: Designed the experiment, conducted the research and wrote the manuscript. Rita Amgain: Managed the data, prepare them for analysis, assisted to data analysis and inference the results. Dinesh Pariyar: Assisted to design, execute the experiments and data recording in the field. Birendra Prasad Budhnagariya, Dina Nath Tiwari: Assisted in implementing the experiments in the stations.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

ETHICS APPROVAL

Not applicable

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