Asian Journal of Crop Science

ISSN 1994-7879

OPEN ACCESS Asian Journal of Crop Science

ISSN 1994-7879
DOI: 10.3923/ajcs.2020.57.62

Research Article
Herbage Mass Productivity and Composition of Weeds in the Mixed Forage Maize-cowpea Field

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Abstract

Background and Objective: The agrestal weeds as a source of forage is a common tradition in some of the tropical countries. A study was done to quantify the effect of different seed rate of maize (*Zea mays* L.) with a fixed stand of cowpea on herbage mass productivity and chemical composition of forage mixture and weeds. **Materials and Methods:** A Completely Randomized Block Design (RCBD) consisting of 4 treatments of maize seed rate, replicated 5 times with a fixed stand of cowpea as intercrop was designed. The herbage dry matter productivity and proximate composition were studied for the herbage harvested at 45 and 75 days after seeding (DAS), respectively. Data analysis was performed by following the analysis of variance (ANOVA) model using GenStat (version 15) software. **Results:** The harvesting time had an effect ($p<0.05$) on herbage-mass productivity of the forage mix, total weed mass and the total biomass, respectively. A maize seed rate of 50 kg ha^{-1} had rather the highest total herbage mass productivity (924.2 t ha^{-1}) at 75 DAS. The harvesting time had a significant effect to almost all of the proximate components except the total minerals content of the weeds, whilst seed rate of maize had affected ($p<0.05$) the total mineral content of the forage mix. **Conclusion:** The research results had shown that weeds could be a valuable and additional forage resource to the conventional maize-cowpea intercropping system as had been shown from herbage mass and rather comparable and almost unchanged crude protein (CP) and total mineral at a later stage of harvest.

Key words: Chemical composition, forage productivity, harvesting time, mix cropping

Citation: Swotantra Dangi, Shanker Raj Barsila, Bijay Sapkota, Badrika Devkota, Naba Raj Devkota and Tugay Ayaşan, 2020. Herbage mass productivity and composition of weeds in the mixed forage maize-cowpea field. Asian J. Crop Sci., 12: 57-62.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Maize is the third most important and dual-purpose cereal crop in the world used respectively in human and animal diet[1,2]. The cowpea (*Vigna unguiculata*) is a well-adapted vine legume with maize[3-5] as well supplies the crude protein[6]. Moreover, there are other practical applications of grass-legume polyculture in the conventional farming systems, e.g. nitrogen fixation[7], increased soil nitrogen[8] and available to other companion crops[9,10]. It is obvious that coevolved weeds reduce major crop productivity[11]. The tropical farmers have learned from the traditional knowledge that the crop weeds provide the additional forage resource[12], besides regarding weeds as ubiquitous plants in the conventional farming system[13,14]. Maize crop weeds have been used abundantly as a source of forage (e.g., in Mexico) that would constitute an interesting amount of feed in the tropical farming system by increasing both the biomass and nutritive value[15]. In the southern plains of Nepal, the weeds have been harvested by the farmers as a source of forage mainly in summer (April-August) as a common tradition of forage collection. The indigenous knowledge of farmers about the selection of weeds as forage, has motivated to conduct the experiment so far. The present study was aimed to quantify the herbage mass productivity and proximate composition of maize-cowpea mix forage and coevolved weeds as an additional forage base in the southern plains of Nepal.

MATERIALS AND METHODS

Study area: The field experiment was conducted at Livestock Research Farm of the Agriculture and Forestry University (AFU) Rampur, Chitwan, Nepal during the summer season (May-September, 2017). Geographically, it was located at 27°37' N latitude and 84°25' E longitudes with an elevation of 256 m.a.sl. According to the geographic classification of Nepal, it falls in the inner Terai region of Central Nepal. The soil was generally acidic (pH 4.5-5.9), light-textured and sandy loam in nature. The site had a typical subtropical climate. The average total annual rainfall was 2200 mm with a distinct monsoon period (>75% of annual rainfall) from mid-June to mid-September[16].

Forage establishment: The maize variety Rampur Composite supplied by National Maize Research Programme of the Nepal Agricultural Research Council (NARC) was used in the experiment. The research design was Completely Randomized Block Design (RCBD) comprised of 4 treatments i.e., maize seed rate 30 (T1), 40 (T2), 50 (T3) and 40 kg ha^{-1} with once weed removal at 30 days after seeding (DAS) as T4. Later, cowpea variety namely Prakash supplied by National Grain Legumes Research Programme of the NARC was applied at the rate of 20 kg ha^{-1} as a mixed legume at all the maize plots. Standard agronomic practices were followed to maintain forage stand in the 5 times replicated plots. Manual broadcasting of maize and cowpea was done and once hand weeding (at 30 DAS) was done in weeding requiring treatment (T4) and other plots were established without weeding. All plots were fertilized with the same amount of fertilizer before sowing, containing 100 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 40 kg of K_2O ha^{-1} with half dose of N in basal and the remaining half was top dressed at 30 DAS.

Herbage sampling: Maize and cowpea forages were manually harvested simultaneously from each plot using a 1×1 m quadrat cutting at 2 times (at 45 and 75 DAS), respectively. Later, the samples were chopped into 3-4 cm in length and labeled into a separate envelope while for oven-drying. The herbage samples were then subjected to oven drying at 60°C until the sample reached the constant weight. Later, the dry matter productivity (t ha^{-1}) was estimated.

Herbage chemical analysis: The dried herbage samples were ground passing through a 45 mm mesh size in the Thomas mill. The ground samples were subjected for proximate analysis[17] in the Animal Nutrition Laboratory of the Agriculture and Forestry University, Nepal to determine crude protein (CP), crude fiber (CF), ether extract (EE) and total ash/mineral content). The crude protein (CP) content was determined as N×6.25 using the Kjeldahl Analyzer. Ether extract (EE) was analyzed by a standard ether extraction method using Goldfish fat extraction method. Crude fiber (CF) was extracted with acid and alkali treatment in succession after the removal of fat and water. The total mineral content was obtained after the complete combustion of the sample in a Muffle Furnace at 600°C.

Calculation of combined chemical composition of maize-cowpea mix: The sample aliquot was calculated based on DM and individual chemical composition i.e., CP, CF, EE and total mineral for the mix of maize and cowpea and a single value of composition were obtained by using the following method[18] Eq. 1:

$$\text{CP (\%)} = \frac{\text{Dry weight of maize}}{\text{Today dry weight of the mixture}} \times \text{CP, CF or EE of maize} + \frac{\text{Dry weight of cowpea}}{\text{Today dry weight of the mixture}} \times \text{CP, CF, EE of cowpea} \quad (1)$$

Statistical analysis: All the collected data were analyzed by using analysis of variance (ANOVA) model by GenStat (Version 15)[19]. The mean difference was set by the Tukey's test ($\alpha = 0.05$) among the treatments. The effect of harvesting time and maize seed rate on dry matter productivity and proximate chemical composition was determined by following two way ANOVA model Eq. 2:

$$Y_{ijk} = \mu + \sigma_i + \beta_j + (\rho\beta)_{ij} + \epsilon_{ijk}$$

Where:

- μ = Constant factor
- σ_i = Effect or ith level of harvesting time
- β_j = Effect or ith level of maize seed rate
- $\rho\beta$ = Interaction effect of harvesting time and maize seed rate
- ϵ_{ijk} = Random error

For the analysis of daily biomass allocation, the one way ANOVA model was used:

$$Y_{ijk} = \mu + \sigma_i + \epsilon_{ij} \quad (2)$$

Where:

- Y_{ijk} = Output of individual observation for parameter
- μ = Over all mean for parameter Y
- σ = Fixed effect of the ith parameter
- ϵ_{ijk} = Residual error

RESULTS

Herbage mass productivity: The time of harvest had a significant effect (p<0.05) on the dry matter productivity except in monocot weeds, however, the monocot herbage mass was significantly affected by only the seed rate of maize. The highest dry matter productivity of forage mix was observed in treatment with 50 and 40 kg ha^{-1} of maize seed rate with once weeding at second harvest stage (about 698-710 t ha^{-1}), whilst the lowest productivity was observed in treatment with 30 kg ha^{-1} i.e., T1 (about 403 t ha^{-1}). The highest dry matter productivity in the total weed was found with maize seed rate 50 kg ha^{-1} at second harvest (about 232 t ha^{-1}). In case of total herbage mass productivity, it was found obviously greater in the second harvest and ranges about 840-925 t ha^{-1} and the highest productivity was found in treatment with 50 kg ha^{-1} of maize seed rate. The detail of the herbage mass productivity of forage mixture and weeds has been shown in Table 1.

The daily biomass allocation of mix forage and weed was observed non-significant (p>0.05), which remained in the range of 8.80-12.30 t/day across all treatments (Table 2).

Herbage proximate chemical composition: Forage mixture at a different seed rate of maize had a similar effect (p>0.05) on CP, CF and EE, except the total mineral content (p<0.05), whilst the harvesting time had a significant effect to all of the components studied. In case of weeds, the seed rate had a similar effect on the parameters of composition, whilst harvesting time had an effect on CP, CF and EE, except for the total minerals. The details of the herbage chemical composition at a different seed rate of maize and harvesting time to forage mixture and weeds have been presented in Table 3.

Table 1: Herbage dry matter productivity (t ha^{-1}) of main forages mixture (Maize+Cowpea) and weeds at 2 different times of harvests

	Harvesting time											
	1st harvest (45 DAS)				2nd harvest (75 DAS)					p-value		
Maize seed rates	T1	T2	T3	T4	T1	T2	T3	T4	SEM	SR	HT	SR×HT
Forage mixture	403.4^{b}	477.8^{ab}	432.4^{b}	404.6^{b}	653.40^{ab}	648.60^{ab}	698.60^{a}	710.3^{a}	56.10	0.90	<0.001	0.68
Monocot weeds	98.2^{ab}	94.2^{ab}	93.8a^{b}	62.6^{b}	83.72^{ab}	119.64^{a}	91.56^{ab}	75.2^{ab}	10.22	0.009	0.470	0.25
Dicot weeds	77.6^{bc}	79.0^{bc}	80.8^{bc}	60.0^{c}	103.40^{abc}	112.32^{ab}	133.96^{a}	111.08^{ab}	9.78	0.16	<0.001	0.43
Total weeds	175.8^{ab}	173.2^{ab}	174.6^{ab}	122.6^{b}	187.10^{a}	232.00^{a}	225.50^{a}	186.3^{ab}	13.82	0.06	<0.001	0.24
Total biomass	579.2^{d}	551.0^{bcd}	607.0^{cd}	527.2^{d}	840.50^{abc}	880.60^{ab}	924.20^{a}	896.6^{ab}	54.70	0.58	<0.001	0.59

T1: Maize seed 30 kg ha^{-1}, T2: Maize 40 kg ha^{-1}, T3: 50 kg ha^{-1}, T4: 40 kg ha^{-1}+weeding once at 30 DAS, SEM: Standard error of the mean, SR: Maize seed rate, HT: Harvesting time, different superscript indicated values significantly different at 5% level of significance within the row

Table 2: Daily above-ground herbage mass allocation of weeds and forage mixture (Maize+Cowpea) at 75 days

	Maize seed rate					p-value
Growth rate (t/day)	T1	T2	T3	T4	SEM	Seed rate
Forage mixture	8.33	5.69	8.87	10.18	4.06	0.73
Monocot weeds	0.48	0.85	0.07	0.42	0.45	0.23
Dicot weeds	0.86	1.11	1.77	1.70	0.31	0.39
Total weeds	1.34	1.96	1.84	2.12	0.76	0.18
Total biomass	9.67	7.65	10.71	12.30	8.82	0.68

Table 3: Proximate chemical composition of forage mixture (Maize+Cowpea) and weeds at two different time of harvest with different 4 seed rates of maize

	Harvesting time											
	1st harvest (45 DAS)				2nd harvest (75 DAS)					p-value		
Maize seed rates	T1	T2	T3	T4	T1	T2	T3	T4	SEM	SR	HT	SR×HT
Forage mix (%)												
CP	5.49^{b}	5.32^{b}	6.32^{b}	7.96^{b}	14.86^{a}	14.27^{a}	14.06^{a}	15.88^{a}	0.659	0.150	<0.001	0.55
CF	9.69^{b}	9.65^{b}	9.43^{b}	12.37^{b}	35.25^{a}	35.45^{a}	36.48^{a}	38.13^{a}	1.012	0.320	<0.001	0.88
EE	2.84^{b}	2.79^{b}	2.81^{b}	2.87^{ab}	3.073^{ab}	2.99^{ab}	3.037^{ab}	3.314^{a}	0.100	0.236	<0.001	0.60
Minerals	3.08^{b}	2.77^{b}	2.90^{b}	4.04^{b}	10.64^{a}	10.66^{a}	10.275^{a}	11.81^{a}	0.448	0.021	<0.001	0.95
Weeds (%)												
CP	15.93^{ab}	16.6^{a}	15.94^{ab}	15.62a^{b}	14.3^{b}	13.91^{b}	14.74^{ab}	15.14^{ab}	0.467	0.942	<0.001	0.14
CF	29.03^{b}	28.97^{b}	28.88^{b}	28.64^{b}	31.29^{a}	31.30^{a}	31.64^{a}	31.05^{a}	0.273	0.474	<0.001	0.81
EE	2.73^{a}	2.73^{a}	2.79^{a}	2.707^{a}	2.60^{a}	2.63^{a}	2.64^{a}	2.66^{a}	0.052	0.766	0.008	0.76
Minerals	10.14^{a}	10.67^{a}	10.86^{a}	10.09^{a}	10.29^{a}	11.08^{a}	11.28^{a}	11.26^{a}	0.284	0.340	0.130	0.33

Different superscript indicated values significantly different at 5% level of significance within the row

DISCUSSION

The agrestal weeds have been considered in a limited number of scientific literature so far as it would have the potential for additional feed base. The goal of the present study was to demonstrate the effect of seed rate of maize with a fixed stand of cowpea on dry matter productivity of weeds and it's quality counterpart in the main forage mixture and the weeds. In addition, the present study was set to overlook the reason why local farmers are interested to use maize weeds as a source of forage. To the knowledge of the authors, this is ever a first report that has intended to quantify the weed mass productivity and proximate composition considerably from the grass-legume intercropped field. Maize intercrops in the conventional farming systems have been so far intended to reduce weed interference [20, 21]. The weed is mostly accounted to the reduction of grain yield due to resource limitations rather than the cause of competition in the conventional farming systems[22]. However, in livestock-forage based systems, intercrops grown in common field crops with higher CP content can be meant for a potential source of forage[23].

As expected, the results of the present study demonstrated that the harvesting time had a significant effect on dry matter productivity and this might be possible alongside the growing period[24]. Furthermore, early weeding had not shown any beneficial effect in terms of nutritive value and dry matter productivity of forage mix in the present study. However, the linear effect of plant density[25] as seed rate of maize applied in the present study on dry matter productivity was less visible and that might have attributed the traditional knowledge of farmers to include weeds as a source of forage. Such a link of the traditional knowledge farmer of using agrestal weeds to the scientific basis had already been mentioned[26].

In the intercropping systems, the higher forage dry matter productivity would be attributed by the higher consumption of resources obviously[27,28], which, however, was not intended in the present study to show up the differences in grass-legume polyculture and monoculture respectively. However, it must be a related principle that the higher biomass might be obtained with the highest seed rate and that was possible without the weeding as expected in the present study.

It's so common in the conventional farming system that the mixtures of grasses and legumes are used extensively for forage production[29]. In general, grass-legume intercropping is done to improve the quality of forage mainly in terms of crude protein[30,31] and maintain the productivity of the land[32] or both[33]. In the present study, it was realized that the competition between forage mix and the weeds could not be ignored as it is expressed as a natural phenomenon as data has been shown from almost unchanged mineral and rather persistent CP content of the weeds. This might be associated with the competitive ability of weeds to better uptake of soil nutrients[34,35]. The CP generally declines at maturity stage over time in response to changing crude fiber content[36], which, however, the trend remained otherwise in forage mix and that might be due to much herbage mass contribution by cowpea as expected and that might also contribute more mineral content at the later harvest.

In the present study, data had well demonstrated that the weeds had incorporated the dry matter and nutritious components alongside the total herbage-mass produced. The weeds at least had 20-30% contribution to the total herbage productivity and with considerably with comparable CP content with the main forage mix and can be a meant for additional forage. The effect of seed rate of maize had a similar effect on CP content of forage mixture and weed in general but remained significant to the ash content of forage mix, while ash content of weeds remained unchanged for seed rate and harvesting time. This might be the reason that the farmers in the tropical world would have considered weeds as forage resource as an inevitable component for feeding livestock.

CONCLUSIONS

The research results indicated that weeds make a pool to the total dry matter productivity alongside the quality composition as has been confirmed by the higher CP content at the tender stage of maize and comparable but almost unchanged mineral content with maize-cowpea mixture. The findings of the present study revealed the dry matter productivity and chemical composition of seasonal and annual weeds could be an alternative to major feeds to livestock feeding in dry summer periods when maize stand per unit land is increased or it can be managed to improve the supply situation by t increasing forage seed rate with a fixed stand of legume as an intercrop. Likewise, the farmer's indigenous knowledge on weed biodiversity has to be further clarified through the social-ecological approach.

SIGNIFICANCE STATEMENT

The study findings revealed that the common field crop weeds would potentiate the additional feed resources in the subtropical world. Harvesting for an increased dry mass in a mixed stand of major forages would be possible either by increasing the herbage stand or considering the seasonal weeds as a forage source. However, the testing of antimetabolites of common weeds is a further need for the inclusion of weeds as a feed resource from the mix forage stands.

ACKNOWLEDGMENTS

The authors would like to thank the Animal Nutrition Laboratory of the Agriculture and Forestry University for supporting the laboratory work. The study project was funded by the Long Term Forage Research Grant (Grant no: Lives/03/016) of the Agriculture and Forestry University/ Department of Animal Nutrition and Fodder Production, Nepal.

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