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Evaluation of Different Forage Species Suitability for Chickpea Double Cropping Under Vertisol Condition

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Abstract: An increasing human population, waterlogging constraints and the associated land shortage are some of the challenges that cause feed scarcity in both quality and quantity for livestock, particularly in the mixed farming system of central land areas of Ethiopia. A two-year field experiment was examined to evaluate different forage species' adaptability and suitability for chickpea double cropping systems under water-logged vertisol conditions during 2020-2021 main cropping seasons. A randomized complete block design with seven treatments and three replications was used. Treatments were Vicia sativa, Vicia Villosa, Vicia Dasycarpa, Cl-8251, Cl-2291, Cl-2806 and fallow. Data was subjected to the general analysis of variance using R software version 4.2. Mean separation was calculated using the least significant difference LSD at a 5% probability level. The finding indicated that the different species of vetch and oat had significantly ($P < 0.05$) affected total biomass yield, days to forage harvest, nutritional quality and yields of successive crops (chickpea). Among treatments, Cl-2291 and Vicia sativa gave the highest (17 t ha^{-1}) and mediate (12 t ha^{-1}) total biomass yield with maturity times of 91 days and 98 days respectively. The effect of different species of forage crops also significantly ($P < 0.05$) affected the productivity of the chickpea double crop. The highest chickpea yield (1819.6 kg ha^{-1}) was recorded from plots that received Vicia villosa species. Most chemical composition was also significantly ($P < 0.05$) influenced by forage type and their species. Relatively better nutritional quality was found in all vetch species, indicating that mixing species of vetch with oats in the proper ratio is essential to improve nutritional quality of lower value. Therefore, we conclude that using species with better biomass yield, particularly leguminous, can increase the feeding and food demands and improve the properties and fertility of the soils under question.

Key words: Chickpea · Double Cropping · Forage Species · Nutritional Quality · Waterlogged Vertisol

INTRODUCTION

The traditional practice of plowing early and late planting brought a wide-scale soil erosion on a vertisol. However, early planting helps establish a good ground cover, which minimizes the direct impact of rain on the soil and compared with late-planted plots, reduces soil erosion by about 100% [1]. If food and fodder production per unit of land area increased by combining better drainage with sequential or double cropping of legumes during most of the year, then people should be able to meet their basic needs for food and fodder [2]. This farming system can bring about a positive effect on the entire landscape and the environment [3-5]. The traditional highland farming system is challenged with several major problems and limitations like Water logging, limited improved crop variety (for double cropping, disease resistance), disease and pest problems especially on chickpeas, traditional way of farming system, not following the recommended agronomic practice and luck of animal feed are common in several areas of highland Vertisols [6]. Limited improved crop variety for double cropping and animal feed are among the bottleneck problems that limit the productivity of waterlogged Vertisols [7].

Different types of forage legume crops can be integrated into cropping systems through several methods such as double or sequential crop farming. There are better chances for these technologies to be acceptable to smallholder farmers than the more expensive conventional pastures. This is because, in the

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above-mentioned methods, the land is tilled for the sake of the food crop and so there is no need for special input for pasture establishment [8]. The farmer is often reluctant to sacrifice arable land for sole pasture production. In this system, however, the farmer is likely to accept the production of food and forage crops together [9-11]. Double or sequential cropping is practiced when two crops (forage and pulse) are grown during a season, one after the other. The essential feature of this system, known as sequential or double cropping, is that the two crops do not overlap, the second being sown only after the first crop is harvested [12]. This cropping is incorporated between any two cereal crop phases according to the traditional crop rotation. A study conducted at DebreZeit Agricultural Research Center showed that a short-duration native forage crop was successfully grown in sequence with chickpeas on a Vertisol to exploit the advantages of producing a double crop of food grain (chickpea or grass pea) and high-quality fodder and improving the nitrogen content of the soil through *Rhizobial* nitrogen fixation by both crops. Therefore, this study was initiated to evaluate forage crops suitable to a double cropping system for chickpeas on Vertisols.

MATERIALS AND METHODS

Description of the Study Area: The experiment was conducted at South West Shewa, Becho Woreda that is located at a distance of 80 km from Addis Ababa. The study area is characterized by a mono-modal rainfall pattern. It was high during the two summer months (July to August), which accounts for 86 percent of the annual rainfall. The average temperature of the area during cropping season was 20°C, respectively. The mean relative humidity is 58.7. The area is situated at an altitude of 2040 m above sea level and is characterized by plateau plains. The controls were arranged in a randomized complete block design with three replications. The experiment was conducted in farmer field conditions. The experimental site was prepared for sowing using oxen drive land preparation practices, which were carried out at the onset of summer rain. The plot size of the trial site was 5m *5m and the net plot size was 4.8 m * 4.8 m. Sowing was taken place in the first week of June. At the time of sowing, the experimental plots were finely delineated manually using rakes and fork diggers. Seeds were sown in rows spaced at 30 cm for vetch and 20 cm for oat on the BBF bed prepared. The treatments were sown according to their recommended seeding rates: 25 kg ha^{-1} for Vicia villosa and Vicia dasycarpa, 30 kg ha^{-1} for Vicia sativa and 80 kg ha^{-1} for oat verities.

Treatments and Experimental Design: Three oat varieties (Vicia sativa, Vicia villosa and Vicia dasycarpa), three vetch varieties (Cl-2291, Cl-2806 and Cl-8251) and control were arranged in a randomized complete block design with three replications. The experiment was conducted at farmer field condition. The experimental site was prepared for sowing using oxen drive land preparation practices, which was carried out at the onset summer rain. The plot size of the trial site was 5m *5m and the net plot size was 4.8 m * 4.8 m. Sowing was taken place at in the first week of June. At the time of sowing, the experimental plots were finely delineated manually using rakes and fork diggers. Seeds were sown in rows spaced at 30 cm for vetch and 20 cm for oat on BBF bed prepared. The treatments were sown according to their recommended seeding rates: 25 kg ha^{-1} for Vicia villosa and Vicia dasycarpa, 30 kg ha^{-1} for Vicia sativa and 80 kg ha^{-1} for oat verities.

Treatments

1. Vicia sativa
2. Vicia villosa
3. Vicia dasycarpa
4. Cl-8251
5. Cl-2291(Dual type)
6. Cl-2806 (Dual type)
7. Fallow

Forage crops were planted as the first crop in the main rainy season. The excess water was drained using BBM from the agricultural fields of a Vertisols area in the main cropping season. Diammonium phosphate (DAP) fertilizer was uniformly applied at 100 kg ha^{-1} for all first-crop treatments. Sowing was done on BBF to improve drainage and reduce water-logging problems of vertisol. The second crop, the chickpea variety that adapted to vertisol condition, was grown using residual moisture. Chickpea seeds were sown at the rate of 150 kg ha^{-1}. The variety used was Mastewal. Phosphorous, in the form of TSP, was uniformly applied at 100 kg ha^{-1}. Chickpea strain was applied uniformly to all plots. Other relevant field trial management practices such as weeding and crop protection were uniformly applied with close supervision during the whole crop growth period.

Soil Sampling and Sample Analysis: Soil samples were taken both before and after planting from the experimental field. Before planting, composited soil samples were collected from a depth of 0-20 cm from the experimental site. After harvesting of second crop, soil samples were collected from each plot at a depth of 0 - 20 cm. The collected soil samples were bagged, labeled and submitted to the Holeta Agricultural Research Analytical

Laboratory. Soil samples were air-dried and ground to pass a 2-mm sieve except for organic carbon and total N in which a 0.5 mm sieve was used. Then, soil samples were analyzed for physicochemical properties following standard laboratory procedures.

Soil Physico-Chemical Analysis: Particle size distribution was determined by the hydrometer method [13]. The pH of the soil was measured from the suspension of 1:2.5 (weight/ volume) soil-to-water ratio using a glass electrode attached to a digital pH meter [14]. Organic carbon content was determined using the Walkley and Black [15] wet digestion method. Total Nitrogen content was determined by the Kjeldahl digestion [16]. Available Phosphorus was extracted using the Bray-II method of Bray and Kurtz [17]. Cation exchange capacity (CEC) and exchangeable bases were extracted by saturating the sample with 1N NH_4OAc and CEC was determined using the ammonium acetate method [18] at the soil and plant analysis laboratory of Holeta Agricultural Research Center.

Data Collection: Data were collected for both for first and second crops. days to forage harvest, plant height, forage dry matter yield and nutritive were collected for forage crops while data of plant height, number of pods per plant, number of seeds per pod, biomass yield and grain yield data were collected for chickpeas.

Growth: The developmental process such as days to emergence and days to 50% flowering were collected.

Plant Height: At herbage harvest for dry matter yield determination, the plant height for each species was determined by measuring the height of five randomly selected plants from ground level to the tip of the main stem. An average of five plants was taken for each plot.

Dry Material Yield: Three adjacent rows from the center of each plot were taken when oats were at the dough stage to estimate fresh biomass yield. The harvested biomass was manually chopped into small pieces using a sickle and a subsample of 300gm fresh weight was taken and dried at 65 °C for 72 hours in an oven for herbage dry matter yield (DMY) determination. Crude protein (CP) yield and neutral detergent fiber (NDFY) of the treatments were further determined as the product of CP and NDF content and herbage DM yield [18].

$$\text{DM yield (t ha)} = (10*TFW *SSDW\ HA\ SSFW) / (HA* SSFW)$$

where:

10 = Constant for conversion of yields in kg/m^2 to t/ha; TFW = Total fresh weight from harvesting area (kg) SSDW = Sub-sample dry weight (g); HA = Harvest area (m^2) SSFW = Sub-sample fresh weight (g).

Besides, a chopped and sun-dried forage sample material for each plot was prepared and saved for chemical analyses.

Sample Preparation and Chemical Analysis

Sample Preparation: The saved samples of forages maintained during herbage harvest were used for chemical analysis. These samples were dried overnight at 600^{0}C in an oven to ease grinding and ground to pass through a 1 mm screen using a Wiley mill. Then samples were weighed according to the chemical parameters analyzed. Weighing of feed samples for chemical analysis was done directly as taken from the oven (hot weighing procedure) to protect against moisture that affects the weight of samples.

Chemical Analysis: The chemical analysis of feed was done using standard analytical methods. The DM and ash contents were determined by oven drying at 105°C overnight and combusting in a muffle furnace at 500°C for 6 hours, respectively. The nitrogen (N) content was determined by the Kjeldahl method and crude protein (CP content was calculated as N x 6.25 [20]. The neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to the procedures of Van Soest and Robertson [21] and in vitro dry matter digestibility (IVDMD) was determined following Tilley and Terry [22]. The analysis of feed samples was done at Holeta Agricultural Research Center (HARC).

Data Analysis: All soil and agronomic data were subjected to statistical analysis of variance using a generalized linear modeling R statistical software version 3.5.3 [23]. The significance of the treatments was tested using the agricolae package of R [24]. The means were compared using the lsmean package of R [25] with LSD set at a 5% level of significance.

RESULTS AND DISCUSSION

Soil Physical and Chemical Properties Before Planting: Selected physicochemical properties were analyzed for composite surface soil (0-20cm) samples collected from

Table 1: Some soil physical and chemical properties of the study site before planting

Parameters	Sand	Silt	Clay	pH	CEC	TN	av.P	OC
Value	14.2	18.8	67	6.97	35.40	0.05	11.66	0.71

Table 2: Effect of different forage crop species on some soil chemical properties after harvesting during the year of 2020 and 2021cropping season

Treatment	pH	OC (%)	av.P (ppm)	TN (%)
Vicia sativa	6.77	0.82	14.66	0.064
Vicia villosa	6.76	0.79	14.92	0.070
Vicia dasycarpa	6.79	0.86	15.73	0.062
Cl-8251	6.89	0.81	13.46	0.065
Cl-2291	6.82	0.85	15.10	0.064
Cl-2806	6.91	0.75	14.39	0.053
No forages	6.88	0.75	12.92	0.074
CV(%)	1.24	7.96	20.26	23.13
LSD(0.05)	NS	NS	NS	NS

Table 3: Performance of forage crops under vertisol area for double cropping systems

Treatments	Dry matter yield (t/ha)	Days to forage harvest
Vicia sativa	6^{c}	98^{bc}
Vicia villosa	8^{b}	112^{a}
Vicia dasycarpa	5^{c}	105^{ab}
Cl-8251	8^{bc}	96^{bc}
Cl-2291	11^{a}	91^{c}
Cl-8206	9^{ab}	98^{bc}
LSD(0.05)	2.07	11.3
CV(%)	20	6.5

Means with different letters within a column are significantly different (P<0.05)

each replication before planting. The results indicated that the soil has 67 % clay followed by 188 silt and 14.2 sand and could be categorized as clay textural class based on USDA Soil Survey Staff [26] soil textural triangle. The mean soil pH of the experimental site was 6.55, which is neutral based on pH ratings proposed by Tekalign [27]. Soil organic carbon, total nitrogen and available phosphorus content of the study area were 0.71 %, 0.05% and 11.66ppm, respectively.

Physicochemical Properties of the Soil after Harvesting: Forage crops have the potential to become an important soil management strategy for simultaneously improving soil quality and enhancing the productivity of succeeding crops because it significantly expands the annual period for effective capture and use of photosynthetic energy when compared with other cropping practices. Soil analysis after harvesting including soil organic carbon, total nitrogen and available phosphorus content of the study site was considerably improved compared to before planting soil results (Table 2).

Dry Mass Yield and Days To forage Harvest: Harvesting crops for biomass reduces the length of the growing period required because neither crop needs to reach reproductive maturity. Maximum accumulation of biomass occurs well ahead of grain ripening in most crops and, therefore, a shorter growing period is required to optimize production. This provides increased flexibility in the management of the two crops and can significantly decrease the total growing season required to produce two sequential crops.

Forage crops and their species significantly ($P < 0.05$) affected dry matter yield and days to harvest Table 3. The present finding showed that the maximum dry mater yield (7.86 t ha^{-1}) was obtained from oat species of Cl-2291 and the minimum value (3.88 t ha^{-1}) was recorded from vetch species of Vicia dasycarpa. Days to forage harvest were significantly ($P< 0.05$) influenced by the type of forage crop and species. The present finding indicated that Vicia sativa and Cl-2291 are early-maturing types of forage crop species with the lowest and highest dry biomass yield respectively. Generally, late-maturing vetch species gave relatively better forage dry matter yield than early-maturing vetch species while early-maturing oat species produced maximum dry matter yield. This might be explained in terms of the difference in the ability of crops or species to utilize and translocation nutrients during the growth periods. Kebede *et al*. [28] reported that late-maturing vetch species gave relatively higher dry mater yield, which take full advantage of the better growing conditions. Conversely, Fekede [29] and Kebede [30] reported that intermediate to late-maturing oats varieties gave comparatively higher forage yield than the early-maturing oats varieties.

Nutritional Composition of Forage Crop Species: Forage quality is influenced by many factors like forage species, stage of maturity at harvest, soil condition and forage growth and variety. The present finding indicated that the highest mean value of DM yield (93.36%) was recorded from the vetch variety of Vicia villosa although

Table 5: Nutrition quality of selected forage crops in the year of 2020 and 2021 cropping season

Treatments	DM (%)	CP (%)	NDF (%)	ADF (%)	ADL (%)	INDMD (%)
Vicia sativa	91.47[c]	11.60[bc]	53.70[c]	38.27[c]	7.99[bc]	57.32[a]
Vicia villosa	93.36[a]	15.20[a]	52.94[c]	40.60[bc]	7.70[c]	55.50[ab]
Vicia dasycarpa	93.05[a]	14.00[ab]	57.70[bc]	43.90[ab]	8.98[ab]	52.40[c]
Cl-8251	92.65[ab]	5.70[d]	66.30[ab]	42.60[a-c]	8.78[a-c]	56.70[a]
Cl-2291	92.96[ab]	8.60[cd]	67.80[ab]	43.90[ab]	8.72[a-c]	55.52[ab]
Cl-2806	92.24[bc]	6.70[d]	68.30[a]	45.80[a]	9.40[a]	53.58[bc]
CV (%)	0.50	17.00	9.80	6.00	6.90	3.00
LSD(0.05)	0.80	3.10	10.4	4.5	1.0	2.90

Means with different letters within a column are significantly different (P<0.05); DM-dry matter; CP-crude protein; NDF- neutral detergent fiber; ADF-acid detergent fiber; ADL-acid detergent lignin; INDMD- In-vitro dry matter digestibility.

it was statistically par with Vicia dasycarpa which gave a DM yield of (93.05%) while the lowest value (91.47 %) was recorded from Vicia sativa.

Significant (P<0.05) CP content of vetch and oat varieties was found among treatments. The mean CP content ranged from 5.70 to 15.20 (Table 5). All varieties of vetch showed better CP content than oat varieties with the highest value found in Vicia villosa. Getnet and Ledin [31] reported that vetch has a higher CP content compared to many other tropical herbaceous legumes. Most herbaceous legumes have a CP content of >15%, a level that is usually required to support lactation and growth, which suggests the adequacy of herbaceous legumes to supplement basal diets of predominately low-quality feeds [32]. CP content should not be used as the only parameter to be considered during quality evaluation. It is the CP yield, which describes the overall and actual productivity of quality forage.

The neutral detergent fiber (NDF) content of vetch and oat species differed significantly (P<0.05) which ranged from 52.94 to 68.30 percent. There were considerable variations among all the tested species. All oat varieties exhibited higher mean values of NDF than vetch varieties. The highest NDF (68.30%) value was found in the oat variety of cl-2806 while the lowest (52.94) value was recorded from the vetch variety of villosa. The NDF contents above the critical value of 60% result in decreased voluntary feed intake, feed conversion efficiency and longer rumination time [33]. The NDF content of all the tested vetch species was found below this threshold level, which indicates higher digestibility while all oat varieties were found above this threshold level showing lower digestibility. Protein and carbohydrates vary with the maturity stage of forage crops. As stems of forage, become mature, protein content decreases and carbohydrate content increases. At full maturity, stage stems make as much as 80% of the total DM and NDF, which indicates the percentage of total fiber (cellulose, hemicellulose and lignin) increases due to increases in xylem tissue [34]. However, the amount of protein is associated with NDF, which increases the ruminal and total tract digestibility [35]. Maximum ADF (45.80) was obtained from an oat variety of Cl-2806 and a minimum value (of 38.27 was recorded from Vicia sativa. The highest acid detergent lignin (ADL) contents were found in the oat variety of Cl-2806 and the lowest value was obtained from the Villosa variety (Table 5). Generally, vetch varieties exhibited higher nutritional value than oat varieties.

The in-vitro dry matter digestibility of oat and vetch species was significantly different. *In-vitro* dry matter digestibility ranged from 52.40 % to 57.32 % with a mean of 54.86%. Maximum (52.40 %) in-vitro dry matter digestibility was found in Vicia sativa while minimum (57.32 %) value observed in Vicia dasycarpa was the lowest. The *in-vitro* dry matter digestibility values higher than 65 percent show good feeding value and values below this level result in reduced intake due to lowered digestibility [36]. The in-vitro dry matter digestibility values observed in this study were above this threshold level for all vetch species except Vicia sativa at both locations, which may implicate higher voluntary intake and digestibility of vetch species.

It was generally observed that early maturing forage had lower in-vitro dry matter digestibility compared to intermediate to late maturity forage crops or species. This could be due to the presence of higher fiber and cell wall constituents and lower CP content in the early maturing than the intermediate to late maturing species. In-vitro dry matter digestibility of any forage crop varied with harvesting stage, fiber and cell wall constituents [36]; proportions of morphological fractions; soil, plant and climate [37]

The basis for double cropping is to better exploit the growing season by using a sequence of crops that are better adapted to specific growing periods within a season. Thus, in areas with an extended growing season and mild winters, it is possible to increase overall

Table 6: Effect of different forage crop varieties on the performance of Chickpea yield and biomass double cropping in the year of 2020 and 2021cropping season

Year	PH	PPP	SPP	By	Gy
2020	35.28	34.85[a]	41.33[a]	3060[a]	1551.17[a]
2021	34.21	22.28[b]	25.85[b]	2013[b]	1365.78[b]
$LSD_{(0.05)}$	NS	2.61	3.1	352	156.34
Varieties					
Vicia sativa	35.9	30.48[ab]	36.92[ab]	3439.3	1706.8[ab]
Vicia villosa	36.36	33.82[a]	40.75[a]	3598.3	1819.6[a]
Vicia dasycarpa	34.43	29.42[ab]	35.42[ab]	3334.8	1566.0[b]
Cl-8251	33.95	26.40[bc]	30.48[cd]	2891.7	1150.6[d]
Cl-2291	35.6	31.30[ab]	33.25[cd]	3108.17	1508.5[bc]
Cl-2806	35.2	21.8[c]	27.65[d]	2624.45	1049.5[d]
Follow	35.2	27.68[b]	33.92[bc]	3242.7	1495.8[bc]
$LSD_{(0.05)}$	NS	5.23	6.14	NS	312.68
$CV_{(\%)}$	8.51	15.64	15.57	16.7	12.33

Treatments with different letters are significantly different at $P \leq 0.05$; PH-plant height PPP- pod per plant; SPP –Seed per pod; By-Biological Yield(kgha^{-1}); Gy-Grain yield (kg ha^{-1})

productivity by harvesting two crops from the same land area. Double cropping of bioenergy feedstock crops has the potential to become an important soil and crop management strategy for simultaneously improving soil quality and producing biomass feedstocks because it significantly expands the annual period for effective capture and use of photosynthetic energy when compared with most current cropping practices (Figure 1). Double cropping is also a recognizable and perhaps more (i.e., producer) acceptable form of landscape management, which has been identified as an approach for integrating multiple bioenergy feedstock sources and biomass residuals into current crop production systems.

Analysis of data showed that different forage types and varieties significantly ($P< 0.05$) affected the grain yield and biomass yield (Table 6). Forage crops (vetch and oat varieties) well performance under waterlogged vertisol had made influence on the second crop (chickpea) which was grown using residual moisture. Better biomass and yield were obtained in the year 2020 than in 2021 due to the extension of rain in the first year. The highest chickpea biomass yield (3598.3 kg ha^{-1}) and grain yield (1819.6 kg ha^{-1}) were obtained from plots that had been planted with Vicia Villosa species. Similarly, maximum plant height, pod per plan seed per pod and SPP of chickpea were recorded from plots that received Vicia villosa as the first crop. This improvement in biomass and grain yield might be due to improvement in the soil micro-environment preceding crop, legume, that can convert atmospheric nitrogen to crop available nitrogen. Different Studies conducted on double cropping systems showed varying results. In a study evaluating single-crop sorghum and sorghum grown in a double-crop sequence with triticale, Goff *et al*. [38] found that double-crop biomass yields were higher for early maturing sorghum varieties when combined with those of triticale, compared with those of a single crop of the same variety planted earlier in the season.

CONCLUSIONS

The increasing human population, waterlogging constraints and the associated land shortage are some of the challenges that cause feed scarcity in both quality and quantity particularly for a mixed farming system in central parts of Ethiopia. Cultivation of improved forages with high biomass yield with reasonable quality that can reach maturity within a short period is essential for such areas. Productivity, nutritional quality and suitability of different forage species for chickpea double crop production were evaluated under waterlogged vertisols. The present finding indicated that the species had significantly ($P < 0.05$) affected total biomass yield, days to forage harvest and nutritional quality. Among oat varieties, Cl-2291 gave the highest total biomass yield and matured early and Villosa produced the maximum biomass yield among vetch species with late maturity time relative to other species. Most chemical composition was significantly ($P < 0.05$) influenced by forage type and their species. Species of vetch showed better CP content than oat varieties with the highest value found in Vicia Villosa. Forage oats exhibited higher mean values of NDF than vetch varieties, which can intake, efficiency and performance of animals. Generally, vetch species and oat varieties varied in most measured parameters including nutritional qualities. These differences are important to select the type of forage crops and species that are best adapted to water-logged vertisol and those suitable and fitted to double cropping while meeting the feeding demands for livestock. Knowledge of forage crops that fit double crop can not only help to obtain higher biomass productivity and to get optimum yield of the second crop but also help to maintain ecological service of vertisol resource when better planning and management are in place.

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