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ORIGINAL ARTICLE

Alfalfa (*Medicago sativa* L.) Green Manuring and Ecological Properties under corn (*Zea mays* L.) culture in Swaziland

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Gcinile N. Nxumalo, E.M. Ossom, R.L. Rhykerd, and C.L. Rhykerd; Alfalfa (*Medicago sativa* L.) Green Manuring and Ecological Properties under corn (*Zea mays* L.) culture in Swaziland

ABSTRACT

Swaziland agriculture is currently faced with the problem of high cost of inorganic fertilizers. One way of addressing this constraint would be developing farming practices that would reduce costs for sustainable agriculture through the involvement of green manure crops such as alfalfa (*Medicago sativa* L.). It is not clear what effects alfalfa could have on ecological properties when associated with corn in a cropping system. Therefore, the objective of this investigation was to assess the influence of alfalfa on ecological characteristics in corn producing There were five treatments: (1), corn with no fertilizer and no alfalfa; (2), alfalfa seeds drilled at 2 kg/ha and biomass incorporated at six weeks after planting (WAP); (3), alfalfa seeds drilled at 2 kg/ha and biomass incorporated at eight WAP; (4), alfalfa seeds drilled at 2 kg/ha; no biomass incorporation, but alfalfa allowed to mature with corn; and (5), corn grown with fertilizer. Results showed that weed density was negatively and significantly correlated to grain yield (r = - 0.612; n = 20).

Key words: Corn * Ecological properties * Green manuring * Organic farming * Soil temperature * Weed infestation * Yields

Soil temperatures were higher at 5-cm depths (highest mean temperature, 30.9°C) than at 10-cm (highest mean temperature, 30.7°C) and 15-cm depths (highest mean temperature, 28.1°C) consistent with earlier research findings. Soil pH improved from 4.5 to 5.3. Alfalfa green manuring was beneficial to soil. It is recommended that small-scale farmers should intercrop corn with alfalfa and incorporate the green legume at six WAP. Further research is required.

Introduction

Organic farming involves growing crops with the use of compost, manure and other natural plant food, without the use of any artificial medicines or man-made plant food [1]. Organic agricultural practices rely on the use of crop residues, animal manures, and the adoption of biological methods to control pests, diseases and weeds. [2] reported that most of the basic nutrient needs of the plant can be locally met through organic source, which makes production sustainable, eliminates the ill effects of fertilizers and reduce the cost of production. According to [1], a green manure crop is a plant grown and later plowed under the soil to enrich the soil. Green manures are usually legume plants with a lot of green leaves, for example, Centro (*Centrosema pubescens*). Green manuring is a low cost, but effective technology in minimizing the investment cost of fertilizers and in safeguarding the productive capacity of the soil [3].

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Growing of leguminous green manure crops such as alfalfa (*Medicago sativa* L.) can add 8-10 tonnes/ha/year of organic matter [4].

Legumes such as alfalfa, sunnhemp (*Crotalaria juncea* L.), and cowpea (*Vigna unguiculata)* contain nitrogen-fixing symbiotic bacteria in the root nodules. These bacteria fix atmospheric nitrogen in a form that plants can use [5]. Green manure increases the percentage of organic matter in the soil, thereby improving water retention, aeration and other soil characteristics. This, therefore, can greatly improve the production of crops, including corn [4]. Alfalfa is also known as Lucerne; alfalfa is an Arabic word that means "best of fodders" [6]. Alfalfa is a cool-season, perennial legume, living from three to 12 years, depending on the variety, climate, and agronomic management. The leaves of alfalfa are trifoliate, and flowers are usually purple. New stem growth starts when older growth produces flowers. The plant grows to a height of up to 1.0 m, and has a deep taproot system, sometimes going down to 4.5 m, and this makes it resilient especially to drought [7]. Alfalfa roots harbor nitrogen-fixing bacteria, *Rhizobia* species, which synthesize atmospheric nitrogen that can be utilized by the crop associated in the farming system with alfalfa. Legumes could be inoculated with the appropriate strain of nitrogen-fixing *Rhizobium* spp. to ensure efficient fixation [8]. Swaziland agriculture is currently faced with the problem of high cost of inorganic fertilizers. One way of addressing this constraint would be developing agronomic practices that lower costs for sustainable agriculture through green manure crops such as alfalfa. It is not known what effects alfalfa could have on ecological properties when associated with corn. Therefore, the objective of this investigation was to assess the influence of alfalfa on ecological characteristics in corn producing.

Materials and methods

Experiment location:

The experiment was conducted at Malkerns Research Station from November 2009 to April 2010. Malkerns Research Station is about 750 metres above sea level and lies at 26.57º South and 31.2º East. The annual rainfall and annual temperatures are 800 mm, and 18ºC, respectively. The soil type is classified under the Malkerns soil series or M-set soil [9].

Experimental design and treatments:

Prior to setting out the experiment, a composite soil sample was taken from the site (0-15 cm depth), and dried in a laboratory oven at 80ºC for 72 hours [10]. After drying the soil was analyzed for pH, nitrogen, organic matter, and potassium concentrations, using standard analytical methods [11]. A randomized complete block design was used for the experiment. There were five treatments, which were replicated four times. The plot size was 4.0 m x 4.5 m and the space between replicates and between plots on all sides was 1.0 m. There were six corn rows per plot: two experimental rows, and four discard rows.

There were five treatments: (1), corn with no fertilizer and no alfalfa; (2), alfalfa seeds drilled at 2 kg/ha and biomass incorporated at six weeks after planting (WAP); (3), alfalfa seeds drilled at 2 kg/ha and biomass incorporated at eight WAP; (4), alfalfa seeds drilled at 2 kg/ha; no biomass incorporation, but alfalfa allowed to mature with corn; and (5), recommended fertilizer treatment for corn. The fertilizer consisted of 300 kg/ha of compound fertilizer, N:P:K, 2:3:2 (37), and 200 kg/ha of limestone ammonium nitrate (LAN) applied to corn.

Liming and planting:

A harrowed tilth was prepared using a tractor-mounted plow and harrow. Based on the pH results of the initial soil analysis, dolomitic lime ($CaMgCO_3$) was broadcast at a rate of 1.65 t/ha, and worked into the soil using rakes, garden forks and spades. Planting of both corn (variety 'SC 403') and alfalfa was done on 28 November 2009. After planting, a rake was used to open furrows of 15-20 mm depth. The alfalfa seeds (2 kg/ha) were drilled 45 cm away from corn rows within each plot. Corn was planted at the inter-row spacing of 90 cm, and intra-row spacing of 25 cm, as recommended [12]. One grain/station was planted, resulting in a plant population of 44,444 plants/ha. Gap-filling of corn was done within one week of corn emergence, to replace grains that failed to emerge.

Fertilizer application and irrigation:

A compound fertilizer, 2:3:2 (37) containing N: P: K and 0.5% Zinc was applied at planting, using the banding and incorporation method. Side-dressing was done using LAN (28% nitrogen) four weeks after emergence using banding and incorporation method. The fertilizer rates were based on the results of the initial soil analysis. Overhead sprinklers were used for to supplementary irrigation for the first four WAP when rains were not regular. On each occasion, the plots were irrigated to field capacity.

Data collection and analysis:

Data were collected on soil temperatures, weed infestation, disease and insect pest infestation, grain yields, and soil chemical properties at the end of the investigation. Soil temperatures at the soil surface, at 5-cm, 10-cm, and 15-cm depths were recorded at 8, 12, and 16 WAP. The soil temperatures were taken using Fisherbrand bi-metal dial soil thermometers with a guage diameter of 4.5 cm, a stem length of 20.3 cm and an accuracy of plus or minus 1.0% of dial range at any point on the dial [13, 14]. The soil temperatures were taken on hot days without rain, and between 1400 and 1600 hours [13, 14].

Weed infestation was assessed at 4, 8, 12, 16 and 20 WAP, using a visual determination of [14] was made using a 90-cm square quadrat and weed density score rating scale from 1 to 6. On this scale, the descriptions were: (1), zero weeds in soil within the quadrat; (2), sparse weed coverage within the quadrat; (3), intermediate weed coverage within the quadrat; (4), General weed coverage within the quadrat; (5), severe weed coverage within the quadrat; and (6), total weed coverage within the quadrat [13, 14]. Three determinations per plot were made. After determining the weed densities, the weed species within the quadrat were identified and classified using weed manuals and textbooks [15]. The percentage of the quadrat occupied by the weeds was determined as the relative abundance of the species within the plot [16, 13, 14].

Plants were examined for disease symptoms at 8, 12, 16, and 20 WAP. A visual determination of disease was made using a 90-cm square quadrat. Three determinations per plot were made. Disease severity was assessed by counting the number of infected corn leaves and rating the symptom expression on a 1-6 scale: (1), complete disease absence; (2), sparse disease presence; (3), intermediate disease presence; (4), general disease presence; (5), severe disease presence; and (6), complete disease presence. [17] had earlier applied a similar method to assess disease incidence. In assessing insect pest infestation, corn plants were examined for insect pest damage at 8, 12, 16, and 20 WAP. A visual determination of insect infestation [18] was made using a 90-cm square quadrat. Insect density score rating scale was 1-6 : (1), complete absence of insect pest; (2), sparse insect coverage; (3), intermediate insect coverage; (4), general insect coverage; (5), severe insect coverage; and (6), complete insect coverage. Three determinations were made in each plot.

Harvesting of maize was done at 20 WAP, when grain yield was recorded. The physiological maturity signs used were: black layer forming at the proximal end of each grain; yellowing of leaves, cobs hanging downwards, and hardness of each grain. Harvesting was done manually, from the two experimental rows in each plot. At harvest, soil samples (0-15 cm depth) were collected from each plot, dried and shipped to the United States for chemical analysis in a reputable commercial laboratory that used recommended analytical methods [11]. Data were analyzed using MSTAT-C statistical program, version 1.3 [19]. The least significant difference was used for mean separation tests at 5% significance level [20].

Results and discussion

Meteorological information: As shown in Table 1, the mean temperature for the period of the experiment ranged from a low of 14.8ºC in November 2009, to a high of 28.2ºC in February 2010. The total rainfall during the time of the experiment was 1013.9 mm. The rainfall was 280.8 mm in January 2010, and decreased to 89.5 mm in February 2010. Low water availability might hinder photosynthesis causing reduced growth and might decrease yields [22]. Water stress would have caused lower yields, but through supplemental irrigation in the beginning and during silking and tasseling, good yields were achieved.

Soil temperatures:

Table 2 shows that soil temperatures at 5-cm depth were generally higher than temperatures at 10-cm and 15-cm depth in all cropping systems. Soil temperatures at all depths showed no significant difference among all the treatments. The observations that soil temperatures were higher at 5-cm depths than at 10-cm and 15-cm depths was consistent with earlier observations [13 & 23] who noted that the temperatures of upper parts of the soil were higher than at lower parts of the soil profile. Greater intense solar radiation at 5-cm depth is another factor, which could contribute to higher temperature in the upper part of the soil profile.

Weed infestation:

Table 3 shows the weed species, which were found in each cropping system during the experiment. The most dominant (34.5% relative abundance) weed species in the corn-no alfalfa and no fertilizer at four WAP was *Richardia brasiliensis,* followed by *Bidens pilosa* L. (relative abundance, 15.2%). *Ipomoea purpurea* L. was the least dominant weed species (relative abundance, 2.1%).

In corn with alfalfa incorporated at six WAP, the most dominant weed species was *Richardia brasiliensis* (relative abundance, 30.0%). *Fallopia convolvulus* L. was the least dominant weed species (relative abundance, 0.7%). *Richardia brasiliensis* also dominated the corn with alfalfa incorporated at eight WAP (relative abundance, 30.5%). *Cynodon dactylon* L. dominated the corn with alfalfa allowed to mature with corn (relative abundance, 34.2%). *Panicum maximum* had the least relative abundance (0.4%). The fertilizer-grown corn had *Bidens pilosa*

Table 1: Meteorological data during the experiment from October 2009 to March 2010.

Month	Temperature (°C)			Total rainfall (mm)
	Maximum	Minimum	Mean	
October 2009	22.2	15.2	18.7	139.9
November 2009	23.8	14.8	19.3	269.0
December 2009	27.3	17.0	22.2	140.3
January 2010	26.4	16.8	21.6	280.8
February 2010	28.2	18.6	23.4	89.5
March 2010	26.4	17.7	22.1	94.4
Totals	154.3	100.1	127.3	1013.9
Means	25.72	16.7	21.2	170.0

Source: [21]

Table 2: Soil temperature at 8-16 weeks after planting in corn-alfalfa association

Cropping system	Soil depth	Weeks after planting			Mean
		8	12	16	
Corn, no alfalfa; no fertilizer	Surface	34.8a	33.5a	32.8a	33.7a
	5 cm	29.7a	29.5a	29.3a	29.5a
	10 cm	30.5a	29.8a	31.8a	30.7a
	15 cm	27.8a	28.0a	28.5a	28.1a
Corn with alfalfa incorporated at 6 weeks	Surface	34.5a	31.3a	31.0a	32.3a
	5 cm	30.0a	30.0a	29.5a	29.8a
	10 cm	29.0a	30.3a	28.5a	29.3a
	15 cm	28.5a	27.3a	28.3a	28.0a
Corn with alfalfa incorporated at 8 weeks	Surface	31.8a	32.0a	32.3a	32.0a
	5 cm	30.5a	31.0a	30.3a	30.6a
	10 cm	31.3a	29.0a	31.5a	30.6a
	15 cm	27.5a	27.8a	27.8a	27.7a
Alfalfa allowed to mature with corn	Surface	33.8a	34.8a	30.8a	33.1a
	5 cm	31.2a	32.0a	29.5a	30.9a
	10 cm	31.0a	29.5a	29.3a	29.9a
	15 cm	27.8a	28.8a	27.3a	28.0a
Corn with fertilizer	Surface	33.5a	35.0a	31.8a	33.4a
	5 cm	31.3a	30.8a	27.8a	30.0a
	10 cm	30.0a	29.0a	29.5a	29.5a
	15 cm	26.8a	27.8a	27.0a	27.2a
Means	Surface	33.7	33.3	31.7	32.9
	5 cm	30.7	30.7	29.3	30.2
	10 cm	30.4a	29.5	30.1	30.0
	15 cm	27.7a	28.0	27.8	27.8
	5 cm	2.30	2.09	2.86	2.42
	10 cm	2.30	2.30	4.40	3.00
	15 cm	1.91	2.14	2.51	2.19

Numbers in the same column followed by the same letters are not significant at $p > 0.05$, according to the least significance difference test.

Table 3: Weed species distribution at 4 weeks under green manuring of corn with alfalfa

Weed species	Common name of weeds	Cropping systems and weed relative abundance (%)[1]				
		Corn, no alfalfa; no fertilizer	Corn with alfalfa incorporated at 6 weeks	Corn with alfalfa incorporated at 8 weeks	Alfalfa allowed to mature with corn	Corn with fertilizer
Acanthospermum glabratum DC. Wild	Five-seeded prostrate starbur	5.1	8.1	10.6	7.7	6.7
Bidens pilosa L.	Blackjack	15.2	10.0	13.6	8.3	30.2
Cleome monophylla L.	Spindlepod	1.6	4.1	1.9	2.6	3.7
Commelina benghalensis L.	Benghal wandering Jew	5.9	1.7	1.6	1.7	0.9
Cyperus esculentus L.	Yellow Nutsedge	10.2	13.2	3.5	6.4	3.4
Cynodon dactylon (L.) Pers.	Common couch	9.3	14.5	30.5	14.8	14.3
Eleusine coracna L.	Goose grass	2.5	1.1	3.6	1.8	0.5
Fallopia convolvulus (L.) Holub.	Climbing knotweed	0.0	0.7	1.1	0.6	1.5
Ipomoea purpurea (L.) Roth.	Common					
Morning glory		2.1	4.5	1.7	1.6	2.0
Panicum maximum	Common buffalo grass	0.0	0.0	1.8	0.4	0.0
Richardia brasiliensis	Tropical Richardia	34.5	30.0	17.8	34.2	19.1
Tagetes minuta L.	Khakiweed	13.8	12.5	12.6	16.2	15.4
Weed density	NA	3.5a	4.b5	3.7a	3.8a	4.4b

[1]Because of rounding up of percentages, the relative abundance may not equal 100%; NA, not applicable

as the most abundant weed species (relative abundance, 30.2%); *Eluesine corcacna* L. was the least (0.5%) in relative abundance.

Table 4 shows the weed species, distribution at eight WAP. The most dominant (38.8%) weed species in the corn with no alfalfa and no fertilizer at eight WAP was *Richardia brasiliensis*, followed by *Bidens pilosa* L. with 10.2% relative abundance. *Fallopia convolvulus* L. was the least dominant weed species. In corn with alfalfa incorporated at six WAP, the most dominant weed species was *Richardia brasiliensis*, (relative abundance, 37.6%); *Panicum maximum* was the least dominant weed species.

Richardia brasiliensis also dominated the corn with alfalfa incorporated at eight WAP (relative abundance, 37.3%), followed by *Bidens pilosa* (relative abundance, 15.9%). Corn grown with fertilizer had *Bidens pilosa* as its most abundant (31.0%) weed species. Correlation studies showed that weed density was positively and significantly correlated to: plant height ($r = 0.556$; $R^2 = 0.309$; $n = 20$); the resultant correlation of determination showed that 30.9% in the variation in plant height could be ascribed to increased weed density. Weed density was negatively and significantly correlated to grain yield ($r = - 0.612$; $n = 20$). The cropping system with alfalfa allowed to mature with corn had lower weed density, in agreement with earlier findings [24, 4] reported that alfalfa hay crops could provide excellent control of problem weeds including wild oat (*Avena fatua*) and Canada thistle *Cirsium arvense*. [25, 26] also reported that alfalfa reduced weed problems and increased productivity of the subsequent grain crops.

Disease infestation:

Table 5 shows the disease scores at 8, 12, 16 and 20 WAP. There were significant ($P < 0.05$) differences in the disease incidence among the cropping systems only at eight WAP.

Corn plants with alfalfa incorporated at 8 WAP had the highest disease score (mean, 3.3), whereas corn plants with alfalfa allowed to mature with the corn had the lowest disease score (mean, 2.9) at 12 WAP. As the cropping season advanced, there was reduced disease incidence in all cropping systems. The two most prevalent diseases were *Cercospora* leaf spot and common rust (*Puccinia sorghi*). Correlation data showed that disease incidence was negatively, but not significantly correlated to a number of parameters: number of leaves ($r = - 0.224$; $n = 20$); leaf area ($r = - 0.005$; $n = 20$); number of cobs/plant ($r = - 0.017$; $n = 20$) harvesting index ($r = - 0.245$; $n = 20$); and yield ($r = - 0.111$; $n = 20$).

Corn plants with alfalfa incorporated had the highest disease incidence, probably because the alfalfa plowed under the soil might have contained spores of rust. As a result, being in contact with the infected alfalfa could have contaminated the corn plants. Corn plants allowed to mature with alfalfa had the least disease incidence, in agreement with agreed with previous findings [25] who reported that alfalfa phases could break pest and diseases cycle in a cropping system. [4] also reported that sunnhemp is an excellent, rapid-growing green manure crop to be included in crop rotation, since it suppresses weeds and reduces disease incidence, among other benefits.

Insect pest infestation:

Table 6 shows insect pest incidence at 8, 12, 16 and 20 WAP. There was no significant difference in the insect pest incidence between the treatments at all sampling times. There was a high insect pest incidence in all treatments at 8 WAP compared to the other WAP. Corn with no fertilizer had the highest (mean insect pest scores, 1.4), whilst corn with alfalfa allowed to mature with the corn had the lowest (mean insect pest score, 1.0) insect pest incidence at 20 WAP. However, as the corn plants grew older and the cropping season progressed, there was reduced insect pest damage on the crop.

Intercropping had been reported to reduce insect pest incidence [27] as also observed in this experiment. The corn plants allowed to mature with alfalfa had the lowest insect pest incidence (mean, 1.0 at 20 WAP), probably because crop association/intercropping reduced insect pest incidence, in agreement with findings of [25] who reported that alfalfa phases could break insect pest and diseases cycles in cropping systems.

Corn yields:

Table 7 shows that there were significant ($p < 0.05$) differences in the number of cobs per plant among the treatments. The plants with fertilizer had a significantly ($p < 0.05$) higher number of cobs/plant than corn plants allowed to mature with alfalfa. Though plants applied with fertilizer had the highest number of cobs per plant (mean, 1.8) than plants incorporated with alfalfa at 6 WAP (mean, 1.7), there was no significant difference in the number of cobs/plant under these two treatments. The corn with no fertilizer and no alfalfa had the lowest number of cobs/plant (mean, 1.5).

The yield of plants applied with fertilizer was not significantly higher than yield of plants incorporated with alfalfa at six WAP, probably was an indication that alfalfa supplied as much nutrients as fertilizer. This agreed with the findings of [28] who reported that corn yields of up to 6.3 t/ha were achieved using alfalfa as the only N source. [29]

Table 4: Influence of different treatments on weed species distribution at 8 weeks after planting

Weed species	Common name of weeds	Cropping systems and weed relative abundance (%)[1]				
		Corn, no alfalfa; no fertilizer	Corn with alfalfa incorporated at 6 weeks	Corn with alfalfa incorporated at 8 weeks	Alfalfa allowed to mature with corn	Corn with fertilizer
Acanthospermum glabratum DC. Wild	Five-seeded prostrate starbur	6.4	11.1	7.9	9.3	5.2
Bidens pilosa L	Blackjack	10.2	13.2	15.9	15.9	14.7
Cleome monophylla L.	Spindlepod	2.1	1.0	1.3	3.8	2.3
Commelina benghalensis L.	Benghal wandering Jew	3.1	1.3	1.3	0.9	1.7
Cyperus esculentus L.	Yellow Nutsedge	9.9	4.8	8.2	7.9	4.5
Cynodon dactylon (L.) Pers.	Common couch	0.0	9.7	5.9	17.5	14.7
Eleusine coracna L.	Goose grass	0.0	4.5	3.3	1.4	0.4
Fallopia convolvulus (L.) Holub.	Climbing knotweed	1.9	0.0	0.0	0.0	1.7
Ipomoea purpurea (L.) Roth.	CommonMorning glory	0.0	4.5	2.0	0.7	2.6
Panicum maximum	Common buffalo grass	0.0	1.0	3.7	0.0	1.3
Oxalis latifolia H.B.K.	Red garden sorrel	8.8	0.0	0.0	0.9	3.8
Richardia brasiliensis	Tropical Richardia	38.8	37.6	37.3	30.0	31.0
Tagetes minuta L.	Khakiweed	18.9	11.2	13.4	12.0	16.0
Weed density	NA	2.6b	3.2b	2.8b	2.0a	3.3c

[1]Because of rounding up of percentages, the relative abundance may not equal 100%; NA, not applicable

Table 5: Disease scores in alfalfa-corn cropping system at 8-20 WAP

Cropping system	Weeks after planting and disease scores				Mean
	8	12	16	20	
Corn, no alfalfa; no fertilizer	1.5a	3.3a	2.0a	1.2a	2.0a
Corn with alfalfa incorporated at 6 weeks	2.0a	3.3a	1.9a	1.1a	2.1a
Corn with alfalfa incorporated at 8 weeks	2.0a	3.2a	1.8a	1.4a	2.1a
Alfalfa allowed to mature with corn	1.7a	2.9a	1.5a	1.0a	1.8a
Corn with fertilizer	2.0b	3.1a	1.8a	1.3a	1.6a
Mean	1.9	3.1	1.8	1.2	2.0

Numbers in the same column followed by the same letters are not significant at p > 0.05, according to the least significance difference test.

Table 6: Insect pests scores at 8-20 weeks

Cropping system	Weeks after planting and insect pest scores				Mean
	8	12	16	20	
Corn, no alfalfa; no fertilizer	3.8a	1.9a	1.8a	1.4a	1.8a
Corn with alfalfa incorporated at 6 weeks	3.4a	1.5a	1.3a	1.1a	1.5a
Corn with alfalfa incorporated at 8 weeks	3.6a	1.5a	1.5a	1.2a	1.6a
Alfalfa allowed to mature with corn	3.8a	1.6a	1.5a	1.0a	1.6a
Corn with fertilizer	3.5a	1.9a	1.0a	1.2a	1.5a
Mean	3.6	1.7	1.4	1.2	1.6

Numbers in the same column followed by the same letters are not significant at p > 0.05, according to the least significance difference test.

Table 7: Number of cobs per plant, harvesting index, and shelling percentage in corn associated with alfalfa

Cropping system	Number of cobs	Harvesting index	Shelling %
Corn, no alfalfa; no fertilizer	1.5a	62.9a	82.9a
Corn with alfalfa incorporated at 6 weeks	1.8b	64.8a	84.1a
Corn with alfalfa incorporated at 8 weeks	1.8b	63.4 a	82.3a
Alfalfa allowed to mature with corn	1.6a	63.0a	83.1a
Corn with fertilizer	1.8b	65.2a	85.4a
Means	1.7	63.9	87.6

Numbers in the same column followed by the same letters are not significant at p > 0.05, according to the least significance difference test.

reported that in trials, corn grain yields, associated with the use of cowpeas as green manure, were doubled compared to unfertilised control treatments. [28]Wilson (1991), further reported that application of Leucaena (*Leucaena leucocephala*) pruning added 5.9-7.1 tonnes dry matter/ha/year and 173-208 kg N/ha/year, increased average corn yields over a four-year period by 1.2 t/ha (200%) over the corn with no N and *Leucaena*. [2] reported that green manure crops increased yield of crops to an extent of 15-20%.

Soil chemical properties:

Table 8 shows the soil properties at harvest. Though there were no significant differences among the various parameters, there were improved concentrations of nutrients and soil acidity. Soil pH

Table 8: Soil chemical properties under alfalfa green manuring

Treatments	O.M (%)	Available P	(cmol/kg) K	Mg	Ca	Soil pH	CEC (cmol /kg)	Per cent base saturation % K	% Mg	% Ca	% H	(cmolc/kg) S	Zn	Mn	Cu	B	$N0_3$-N	Total N (%)
Corn: no fertilizer; no alfalfa	4.0a	24.0b	86.5b	128.8a	312.5b	5.4a	4.7b	4.9a	22.8b	33.4c	39.0b	12.8a	3.7b	6.5a	1.1b	0.2a	5.0a	0.117b
Alfalfa, 2 kg/ha incorporated at 6 weeks	3.9a	21.8b	96.5b	106.3a	275.0b	5.2a	4.6b	5.4a	19.0b	29.6c	46.0b	14.0a	3.7b	5.8a	1.1b	0.2a	4.5a	0.119b
Alfalfa, 2 kg/ha incorporated at 8 weeks	3.8a	23.0b	94.0 b	98.8a	250.0b	5.2a	4.4b	5.5a	18.4b	28.0c	48.2b	14.3a	3.9b	4.5a	1.1b	0.2a	5.5a	0.090b
Alfalfa, 2 kg/ha; maturing with corn	3.9a	25.0b	88.0 b	115.0a	350.0b	5.3a	5.0b	4.a	18.7 b	33.8c	43.1b	14.0a	3.9b	5.5a	1.1b	0.2a	3.8a	0.110b
Corn with fertilizer	3.7a	28.5b	100.8b	118.8a	300.0b	5.2a	4.9b	5.3a	20.6b	31.1c	43.0b	13.3a	3.7b	8.0a	1.1b	0.2a	7.5	0.094b
Mean	3.8	24.5	93.2	113.5	297.5	5.3	4.7	5.1	19.9	31.2	43.9	13.7	3.8	6.1	1.1	0.2	5.3	0.106

Numbers in the same column followed by the same letters are not significant at $p > 0.05$, according to the least significance difference test.

increased from 4.5 to 5.3, showing that improved levels of nutrient elements could become more available at the higher pH. Available P was extremely low in the initial soil sample (0.48 cmol/kg), but leapt to 24.5 cmol/kg) by harvest time. Other improved levels of increases were: K, 0.03-93.2 cmol/kg, Mg, 0.96-113.5 cmol/kg; and Ca, 0.12-297.5 cmol/kg.

Conclusion and recommendation

Green manuring with alfalfa improved corn yields, reduced soil acidity and reduced weed infestation. It is recommended that farmers should intercrop corn with alfalfa and incorporate the alfalfa at six WAP. Further research is needed to validate the results before the small-scale farmers are encouraged to sow corn with alfalfa.

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