Research Article

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Effectiveness of cowpea (*Vigna unguiculata* L.) living mulch on weed suppression and yield of maize (*Zea mays* L.)

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Abstract: Weed control plays a vital role in achieving higher maize yield. We tested the hypothesis that inter-seeding cowpea as living mulch with maize will reduce biomass and diversity of weeds, and improve soil physical properties and maize yield. In 2017/2018 cropping seasons, a 2×4 factorial experiment was laid in a randomized complete block design with three replications at the Savelugu Municipality of Northern Ghana. The factorial treatment consisted of three cowpea varieties inter-seeded with two maize genotypes and a control (maize with no living mulch). Our result showed that, in both seasons, weed biomass and diversity, soil temperature, and grain yield were significantly ($p < 0.05$) higher in control plots than in cowpea living mulch plots at all growth stages of both maize varieties. However, maize growth was not affected by weeds at tasseling. We established that cowpea varieties as living mulch in maize cropping have similar effect on soil moisture and temperature but have varying degrees of suppressing weeds and improving maize yield. The cowpea living mulch had weed biomass of 0.5 t ha^{-1} compared to 2.6 t ha^{-1} in the control. In addition, living mulch plots had maize grain of 2 t ha^{-1} and stover yield of 3 t ha^{-1} compared to 0.98 and 2 t ha^{-1} respectively in the control. In conclusion, choosing the appropriate time for intercropping living mulches and selection of plant species (growth and canopy cover) for living mulch are essential in suppressing growth of weeds.

Keywords: weed suppression, living mulch, maize, varieties, cowpea

1 Introduction

Maize (*Zea mays* L.) is one of the major cereal crops produced and consumed in sub-Saharan Africa [1,2]. In Ghana, maize is the highest cultivated cereal crop (1 million hectare), representing 50–60% of total cereal production [3].

Regrettably, grain yield of maize on farmers' field in Ghana is about 1.9 t ha^{-1} compared to an estimated attainable yield of 6.0 t ha^{-1} [4,5]. This low yield has been attributed to several factors among which are poor soils and inadequate and untimely weed control [3,6]. In relation to the later cause, Romaneckas et al. [7] and Mohammadi et al. [8] stressed that weed control plays a vital role in achieving higher yield as its infestation is one of the principal constraints facing maize production. This constrain has been associated with the ability of weeds to outcompete maize for water, light, nutrients, and carbon dioxide [7,9]. More worrisome is the fact that maize at the early stages of growth is highly susceptible to weed competition, and inadequate and untimely weed control could lead to yield losses of about 40–90% [9–11].

Because of these negative impacts, herbicide application has been recommended as a conventional method of weed control. However, in recent times, most small-holder farmers (80%) in Ghana have not been applying these herbicides because they have become too expensive and there are increased reports of misapplication [4,12,13]. In addition, application of herbicides causes negative effects on the environment, food/farmers' health, and developing resistance of weeds [13,14].

Therefore, many authors [12,13,15] have called for an alternative method of suppression/control of weeds that guarantees good crop yield, safety to farmers and the environment. Consequently, Mohammadi et al. [8], Ram et al. [11], and Wang et al. [16] have argued that when legumes plants such as cowpea are introduced into cropping systems as living mulch, they could offer an important ecological approach to weed suppression and soil fertility improvement.

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For instance, cowpea is known to fix about 240 kg ha^{-1} of atmospheric nitrogen and make about $60\text{--}70 \text{ kg ha}^{-1}$ of the nitrogen to intercropped and succeeding crops, and this limits the need for inorganic fertilizers [13,17].

Therefore, in the present study, we selected three cowpea varieties (Apagbala, Padituya, and Nandanbaya) and two varieties of maize; “Abontem” (extra early maturing, 75 days) and “Omankwa” (early maturing, 90 days). These varieties are among the most cultivated among smallholder farmers (80%) in Ghana [18,19].

We tested the hypothesis that interseeding cowpea as living mulch in plots grown with maize will reduce biomass and the diversity of weeds, and improve the physical soil properties and the yield of maize.

2 Materials and methods

2.1 Description of study site

The study was conducted under on-farm conditions, during the 2017 and 2018 cropping seasons, at Duko (09.55879 N, 0.8200 W), a community located in the Savelugu Municipality of Northern Ghana. The study area lies within the Guinea Savanna agroecological zone of Ghana, with a warm climate of temperature range of $24\text{--}29^\circ\text{C}$. The area is characterized by a mono-modal rainfall with an annual rainfall range of $900\text{--}1,000 \text{ mm}$, which spans between April and early November each year (Figure 1).

During the study period, the month of August recorded the highest total monthly rainfall as well as the lowest mean

monthly minimum and maximum temperature, while the month of June received the lowest total rainfall, with the highest mean monthly temperature values recorded by the month of May (Figure 1).

2.2 Experimental design

The experiment was a 2×4 factorial experiment laid in a randomized complete block design (RCBD) with three replications. A factorial treatment combination consisting of four cowpea living mulch systems: no living mulch (control), Apagbala living mulch with maize same day, Padituya living mulch with maize same day, and Nandanbaya living mulch with maize same day.

There were eight plots (treatments) in each replication, with each plot measuring $4.5 \times 4.0 \text{ m}$ with an alley of 1 m between living mulch plots and an alley of 2 m between maize maturity types.

2.3 Description of maize and cowpea varieties

The Abontem and Omankwa maize varieties were developed by the Council for Scientific and Industrial Research (CSIR) of Ghana and released in 2010. The Abontem is usually described as extra early maturing (75 days) while Omankwa maize variety is early maturing (90 days). The Abontem has a potential yield of about 4.7 t ha^{-1} with seed type being yellow flint. It is most suitable for the

Figure 1: The monthly pattern of rainfall and temperature at the study site during the experiment (2017/2018 cropping season).

Table 1: Growth characteristics and preferred ecology for cultivation of the three cowpea varieties

Cowpea variety	Growth characteristics	Preferred ecology for cultivation
Apagbala	<ul style="list-style-type: none"> • Erect with determinate growth habit • Early maturing (60 days after sowing) • It is high in fodder/grain yield 	Sahel, Sudan, Derived Guinea savanna zones
Padituya	<ul style="list-style-type: none"> • Has erect plant stature with few vines and large thick leaves • Matures in 64–67 days • Majority of the pods are slightly above the canopy • The percent harvest in total yield (determinacy) is moderate, about 72% 	Sudan, Derived Guinea savanna zones
Nandanbaya	<ul style="list-style-type: none"> • Has erect plant stature with few vines and medium thick leaves • Matures in 64–67 days • The brown mature pods are normally three per peduncle • Majority of the pods are slightly above the canopy • The percent harvest in total yield (determinacy) is moderate, about 65% 	Sahel, Sudan, Guinea savanna zones

Source: Okese [18]; Wahaga [19].

Guinea and Sudan savanna agroecological zones of Ghana. However, the Omankwa has a potential yield of about 5 t ha^{-1} with white flint/dent seed type. It is most suitable for forest and forest transition zones. However, both maize varieties are drought and striga tolerant.

The three cowpea varieties were released by the CSIR of Ghana from 2002 to 2008. They have varied morphological growth characteristic and generally adapted to the Sahel, Sudan, and derived Guinea savanna zones of Ghana (Table 1).

The grain yield of maize was determined from the two middle rows within a net plot area of 6 m^2 . The maize cobs were harvested (in September–October, 2017/2018 cropping season) at physiological maturity, dehusked, and oven dried at 65°C to a moisture content of 13% before shelling to measure the grain weight. It was then converted into tons per hectare. After harvesting the cobs, the plants were cut at ground level and oven dried at 65°C for 72 h to a constant weight before measuring stover yield. It was then expressed as tons per hectare.

2.4 Agronomic practices during the experiment

The maize was planted (in May 2017/2018 cropping season) at a spacing of $75 \times 40 \text{ cm}$ and interseeded with cowpea at rows between the maize plants to make a ratio of 1:1 row arrangement. The maize was planted at three seeds per hill and thinned to two seeds per hill 10 days after planting (DAP), while the cowpea was planted at two seeds per hill. The cowpea was planted at 20 cm intra-row spacing between the rows of the maize plants.

A compound fertilizer, NPK (15–15–15) was applied at 30 kg N ha^{-1} , $30 \text{ kg P}_2\text{O}_5$, and $30 \text{ kg K}_2\text{O ha}^{-1}$ as a basal application to all maize plants 7 DAP and top dressed at 20 DAP with sulfate of ammonium at 30 kg N ha^{-1} .

The WatchDog 2000 Series Weather Station was installed at the experimental site to measure the following weather parameters: precipitation (mm), temperature ($^\circ\text{C}$), relative humidity (%), and solar radiation (W/m^2) on a monthly basis during the cropping season.

2.5 Assessment of biomass and diversity of weeds

A 1 m^2 quadrat was used to measure weed species diversity at 6 weeks after planting the maize. The quadrat was randomly placed thrice in the middle of each plot along the diagonal. The weeds in each quadrat were then identified and scored using a scale of 0–4 where 0 = no occurrence, 1 = 1–2, 2 = 2–5, 3 = 6–20, and 4 = >20 plants of the weed species. The average weed occurrence in each treatment plot was calculated using the summed dominance ratio (SDR) approach by Dzomeku et al. [20]:

$$\text{SDR (\%)} = \frac{1}{2} \frac{\sum F}{\sum \sum F + \sum \sum D} \times 100,$$

where F is the frequency of occurrence of a weed species within a treatment plot and D is the density of occurrence within a treatment plot.

At harvest, the weed biomass was determined using the 1 m^2 quadrat. The quadrat was used to capture weeds

Figure 2: The effect of cowpea living mulch types on weed biomass in maize plots (average of 2017/2018 cropping season). Bars represent standard error of means and bars with different letters are significantly ($p < 0.05$) different.

by placing it randomly thrice in the middle of each plot along the diagonals. The weeds were then cut at ground level, put into an envelope, and oven dried at 65°C for 72 h to a constant weight as weed biomass.

2.6 Data analysis

Data collected were subjected to the general linear model of the statistical analysis software, Statistix 10. The analysis of variance (ANOVA) procedure for RCBD with three replications was used to determine whether there was significant difference among treatment. Least significant difference (LSD) was also used to separate treatment means of significant difference at 5% probability level.

3 Results

3.1 Weed biomass and diversity on maize plots interseeded with cowpea living mulch types

Weed biomass was significantly ($p < 0.05$) higher in the control plots (2.6 t ha^{-1}) than in plots with any of the cowpea living mulches at the vegetative, tasseling, and harvest stages of both maize varieties (0.5 t ha^{-1}). However, weed biomass was similar among the cowpea living mulch types (Figure 2).

Eighteen dominant weed species were identified at 6 weeks after planting. The weed species were classified into grasses and broadleaves (Table 2). The cowpea living mulch types had varied diversity and score of weeds;

however, weed species diversity under all non-mulched plots (control) was higher than that of the living-mulch plots (Table 2).

3.2 Effect of cowpea living mulch types on soil temperature and moisture content

The different types of cowpea living mulch had a significant ($p < 0.05$) effect on soil temperature at vegetative and tasseling growth stage of the two maize varieties. The control (no mulch) plots recorded the highest soil temperature (Figure 3). Among the cowpea types, Apagbala living mulch had the lowest soil temperature and this was similar to Nandanbaya living mulch. However, soil temperature for both Apagbala and Nandanbaya living mulch types were significantly ($p < 0.05$) different from Padituya living mulch and the control–no living mulch (Figure 3).

The soil moisture content varied ($p < 0.05$) among the living mulch types at the various growth stages of both maize varieties. Generally, soils with all the cowpea living mulch types had higher ($p < 0.05$) moisture content at vegetative, tasseling, and harvest stages of both maize varieties (Table 3). At the various stages of maize growth, the lowest soil moisture content (average of 16%) was recorded at harvest (Table 3). For example, at vegetative stage of both maize varieties, the different living mulch types had similar soil water content; however, at tasseling, Apagbala mulch had the highest ($p < 0.05$) soil moisture followed by Padituya (Table 3). The different living mulch types were however similar in their soil moisture content at harvest, even though plots planted with Omankwa maize variety had higher soil moisture.

Table 2: Weed species and average weed score affected by maize maturity type and cowpea living mulch type at harvest

Weed species	Abontem				Omankwa			
	Sole	Apagbala	Padituya	Nandanbaya	Sole	Apagbala	Padituya	Nandanbaya
Grasses								
<i>Panicum laxum</i> Sw.	4.0	4.9	8.8	7.3	5.1	12.9	4.9	11.6
Total	4.0	4.9	8.8	7.3	5.1	12.9	4.9	11.6
Broadleaves								
<i>Ageratum conyzoides</i> L.	7.9	3.7	4.4	4.8	5.1	—	8.5	—
<i>Commelina benghalensis</i> L.	3.0	3.7	3.4	—	7.7	4.9	—	—
<i>Corchorus olitorius</i> L.	12.9	13.6	10.9	15.6	6.3	12.9	13.4	10.3
<i>Hyptis spicigera</i> Lam.	5.9	6.2	6.5	6.0	6.3	5.9	6.1	6.1
<i>Ipomoea triloba</i> L.	3.0	4.9	—	—	3.9	6.1	—	4.2
<i>Leucas martinicensis</i> (Jacq.) R.Br.	7.0	—	—	—	5.1	4.0	3.6	4.2
<i>Ludwigia decurrens</i> Walter	10.8	12.3	12.9	14.3	12.6	9.8	13.5	12.2
<i>Mitracarpus villosus</i> (Sw.) DC.	8.9	12.3	5.4	10.8	10.1	4.0	11.0	9.4
<i>Oldenlandia herbacea</i> (L.) Roxb.	7.9	4.9	12.2	8.5	—	7.0	8.5	4.2
<i>Phyllanthus amarus</i> (Schumach. & Thonn.)	3.0	—	—	—	—	—	3.6	—
<i>Portulaca quadrifida</i> L.	8.9	9.9	9.9	14.5	16.4	13.8	8.5	9.4
<i>Schwenckia americana</i> L.	9.8	16.0	14.3	13.3	12.6	3.0	12.1	8.4
<i>Scoparia dulcis</i> L.	4.0	3.7	4.4	—	5.1	8.9	—	9.4
<i>Stachytarpheta cayennensis</i> (Rich.) Vahl	3.0	3.7	3.4	—	—	4.0	6.1	4.2
<i>Tridax procumbens</i> L.	—	—	3.4	—	—	—	—	—
<i>Vernonia ambigua</i> (Kotschy & Peyr.)	—	—	—	4.8	3.9	3.0	—	6.5
Total	96.0	95.1	91.2	92.7	94.9	87.1	95.1	88.4
Coefficient of variance (%)	14	21	17	23	19	20	17	19

3.3 Height, stover, and grain yield of maize after using different cowpea varieties as living mulch

The maize variety × cowpea living mulch type had no significant effect on maize height. However, among the

living mulch types, the Padituya living mulch produced the tallest (96 cm) maize plants at vegetative growth and this was significantly ($p < 0.05$) higher than the other two living mulch types, with the control producing the shortest plants of 87 cm (Table 4). But at tasseling growth stage, the height of maize was similar among all the

Figure 3: The interaction effect of maize maturity type × cowpea living mulch type on soil temperature at vegetative and tasseling growth stage. Bars represent standard error of means and bars with different letters are significantly ($p < 0.05$) different.

Table 3: Average soil moisture content affected by cowpea living mulch types at different growth stages of two maize varieties

Cowpea mulch type	Soil moisture content at different maize growth stages (%)					
	Vegetative stage		Tasseling		Harvest	
	Abontem	Omarkwa	Abontem	Omarkwa	Abontem	Omarkwa
Control	21.32 ± 0.06 ^b	19.5 ± 0.08 ^c	18.3 ± 0.04 ^d	17.1 ± 0.03 ^d	11.2 ± 0.01 ^b	10.7 ± 0.04 ^d
Apagbala	27.84 ± 0.08 ^a	22.6 ± 0.04 ^b	25.3 ± 0.02 ^a	21.6 ± 0.09 ^{bc}	16.0 ± 0.01 ^a	16.9 ± 0.09 ^{bc}
Padituya	26.61 ± 0.06 ^a	26.1 ± 0.10 ^a	24.6 ± 0.07 ^{ac}	25.1 ± 0.02 ^a	14.9 ± 0.05 ^a	19.0 ± 0.11 ^a
Nandanbaya	26.90 ± 0.07 ^a	25.7 ± 0.09 ^a	23.9 ± 0.01 ^c	22.2 ± 0.05 ^b	15.6 ± 0.03 ^a	17.1 ± 0.06 ^b
LSD (0.05)	1.80	1.64	1.21	1.09	1.12	0.98
<i>p</i> -value	*	*	*	*	*	*

Mean values followed by the same letters in each column are not significantly different.

* = *p*-value ≤ 0.05; ± = standard error of means.

living mulch types and the control. The pattern was different at harvest where all the living mulch types produced similar maize plants (187 cm) which were significantly ($p < 0.05$) higher than the control treatment (Table 4). One living mulch type, Padituya, was statistically similar to the control though taller at 185 cm (Table 4).

Maize grain and stover yield were not influenced by maize maturity type. However, both maize grain and stover yield were significantly ($p < 0.05$) influenced by cowpea living mulch type. For example, Nandanbaya living mulch produced the highest maize grain and stover yield of 2.2 and 3.7 t ha⁻¹ respectively, while the control had the lowest grain (1.0 t ha⁻¹) and stover (2.5 t ha⁻¹) yield (Figure 4).

4 Discussion

In this study, we tested the hypothesis that interseeding cowpea as living mulch in plots grown with maize will

reduce diversity and biomass of weeds and, in addition, will improve the soil physical properties and the yield of maize. Our result showed that cowpea living mulch types can be used as an agronomic management strategy in controlling different species of weeds on maize farms considering that all the living mulch types contributed to the reduction in weed biomass and diversity, such that the control–no living mulch produced the highest weed biomass and diversity (Figure 2 and Table 2). This confirms the earlier suggestions, by Teasdale and Mohler [21] and Talebbeigi and Ghadiri [22], that living mulches could form an important component in agroecosystems management and used as a tool for weed suppression in sustainable agriculture systems.

Several authors have attributed the suppression of weeds by living mulches to their ability to outcompete the weeds for light, moisture, and nutrients [23–25]. In addition, the high soil moisture and low temperatures recorded on plots with living mulch compared to the control (Figure 3 and Table 3) could have suppressed the growth of the different weed species.

These environmental effects have been reported as requirements for breaking seed dormancy and promoting germination of weed seeds [24,26].

For instance, Travlos *et al.* [27], Gardarin *et al.* [28], and Koger *et al.* [29] mentioned that low soil temperature (25–30°C) and water content can exert a great influence on the germination, growth, and composition of weed in a cultivated area, a phenomenon Wang *et al.* [16] attributed to the less exposure of the weed seeds to heat-shock since weed seeds require higher (about 30°C) temperature to break their dormancy. However, contrary to the believe that soils with potential nitrogen release could promote weed seed germination [30], we found that on plots with cowpea (a nitrogen fixing plant) living mulch, density and diversity of weeds were lower, thus confirming

Table 4: Maize plant height (cm) as affected by cowpea living mulch types (average of the two maize varieties)

Cowpea living mulch types	Maize growth stage		
	Vegetative	Tasseling	Harvest
Control (no living mulch)	86.9 ^b	124.7	175.4 ^b
Apagbala	92.7 ^{ab}	124.5	187.5 ^a
Padituya	95.8 ^a	125.5	184.9 ^{ab}
Nandanbaya	90.9 ^{ab}	124.6	187.3 ^a
LSD (0.05)	7.9	ns	11.4

Mean values followed by the same letters in each column are not significantly different from one another.

ns = no significant difference.

Figure 4: The effect of cowpea living mulch types on maize grain and stover yield (average of the two maize varieties and the cropping season). Bars represent standard error of means.

the position of previous researchers that nitrogen in soils could stimulate seed dormancy in weeds [27,31,32].

We also found that the cowpea types exhibited different suppression abilities of weeds at different growth stages of the maize varieties. This could be because of the differences in the growth and morphological architecture of the cowpea varieties (Table 1). For instance, the success of Padituya and Nandanbaya in suppressing more weed growth could be because of their erect stature characterized by their large thick leaves which could have provided quick and thick canopy cover thereby suppressing growth of weeds. This therefore shows that apart from choosing the appropriate time for intercropping living mulches [33], mulch species selection (nature of growth and canopy cover) could be essential in shading or mechanically blocking the growth of weed species.

In relation to maize height and yield, the living mulches positively influenced the height, grain, and stover yield of both maize varieties. We found that all maize plots interseeded with cowpea living mulch produced grain and stover yield higher than the no living mulch (control). The difference in height and grain yield could be as a result of enhanced soil nutrients (e.g., nitrogen), which is associated with legume plants like cowpea. The findings of Radicetti et al. [34] and Wang et al. [16] affirm our assertion, as they reported better crop nitrogen status and estimated a higher total N-uptake and improved yield (e.g., wheat) in living-mulch plots than in no-mulch/monocrop systems. Therefore, our findings provide the alternative to the majority (80%) of smallholder low resource farmers who depend on maize cultivation but are confronted with problems of weeds and cannot afford inorganic fertilizer to meet the nitrogen and other nutrients' needs of their farms.

5 Conclusion

We have established that the use of any of the most cultivated cowpea varieties in Ghana (Padituya, Apagbala, and Nandanbaya) as living mulch in maize cropping system has the potential to suppress different growth and biomass of weeds to 0.5 t ha^{-1} compared to 2.6 t ha^{-1} in the control. In addition, living mulch plots had increased maize grain of 2 t ha^{-1} and stover yield of 3 t ha^{-1} compared to 0.98 and 2 t ha^{-1} respectively in the control. Finally, in addition to choosing the appropriate time for intercropping living mulches; mulch species selection (nature of growth and canopy cover) is essential in shading, suppressing, or mechanically blocking the growth of weed species.

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