Effects of Biodegradable Mulch Films in Common Bean (*Phaseolus vulgaris* L.) Performance: On-station Trials

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Abstract

Different types of mulches have varied levels of efficiency. This study compared effects of using biodegradable mulch films (BMF) in common beans production compared with selected types of dead mulches used in Tanzania. Two different experiments in four replications were conducted using completely randomized block design on-station at SUA. In the first experiment, the treatments were BMF, pimento grass, maize straw and control. In the second experiment the treatments were BMF, butterfly pea, maize husks, and control. Crop performance indicators including germination, number of leaves, plant height and number of pods were recorded weekly using 9 representative plants in each plot. Number of weeds were counted physically weekly using quadrant method. Dry grain yield was also recorded in each experiment. The data were analysed for the effects of treatments to experimental units using ANOVA at 5% significance level. Results from the first experiment showed that BMF performed significantly better than other tested mulches in yield, weed control, branching, number of leaves, and number of pods. BMF did not do well in seed germination and plant height. Results from the second experiment showed that BMF had significantly better performance in terms of number of pods, grain bean yield, weed infestation control, plant height and number of branches. These initial results on use of industrial BMF calls for further research which may lead to promotion of use of these environmentally friendlier mulch films as compared to very slowly degradable plastic mulch films currently used in some farming systems in Tanzania.

Keywords: Biodegradable mulch films, common beans, dead mulches, soil moisture conservation

Introduction

Domestic consumption and commercial use of common bean (*Phaseolus vulgaris*) in Tanzania exceed by a far margin other legume crops (Mishili *et al.,* 2011; Birachi *et al.,* 2020; Kilima & Bolle 2020). Common beans are rich in protein contents for an estimated range 22-38% of protein (Binagwa *et al.,* 2018) and contain digestible starch of an estimated range of 61 - 73% (Zhang *et al.,* 2022), making it an important crop for food and nutritional security. The crop grows in almost all agroecological zones of Tanzania and its production practices span all the scales of farming, from small to large scale. Binagwa *et al.* (2018) reported that small scale farmers contribute to over 70% of national bean production, while about 60% is for their own consumption and about 40% is for markets. Despite this importance, the national average yield of the crop which ranges from 0.72 to 1.10 tones ha^{-1} is below the potential production in the country which ranges from 1.5 to 3 tones ha^{-1} (Musimu, 2018; Sampaio *et al.,* 2020). Several factors contribute to this discrepancy including degradation of soil physical and chemical properties, climatic, agronomic and management factors (Bucheyeki & Mmbaga, 2013; Porch *et al.,* 2013; Musimu, 2018).

Application of mulches has been reported to improve soil, microclimate and management conditions in croplands, thus improving productivity. Mulches prevent water loss from the soil by reducing evaporation, influencing soil temperature, minimizing weed growth, adding soil organic matter, and creating conducive microclimate for microbial activities (Iqbal *et al.,* 2020; Kwiecien *et al.,* 2018). However, the effectiveness depends on type of mulch materials and how it is applied. Apart from the benefits, some mulch types may have negative effects. These include addition of weed seeds in case of improper use of dead plant mulches, and environmental pollutions in case of use of synthetic plastic mulches (Du *et al.,* 2022). Thus care need to be taken on choice of type and application of mulches.

The use of synthetic mulch films is gaining popularity. Biodegradable mulch films (BMFs) offer an environmentally sustainable alternative to conventional polyethylene (PE) mulch which have low biodegradability (Menosi *et al.,* 2021), thus staying in the environment for longer time causing polution (Ruiz *et al.,* 2021). Unlike PE films, which need to be removed after use (Sintim *et al.,* 2019), BMFs are tilled into soil where they are expected to biodegrade (Yang *et al.,* 2020). The BMFs have been developed as substitutes to PE mulch films and are designed to be tilled into soil after use where are degraded by resident microorganisms such as Aspergillus, Penicillium, and Acanthamoeba fungi (Souza *et al.,* 2020). BMFs can be prepared from biobased polymers derived from microbes or plants, or fossil-sourced materials (Li *et al.* 2014). Repeated tilling of BMFs fragments into soil may alter the soil physical environment and act as a new source of carbon for microbes (Bandopadhyay *et al.,* 2018; C. Zhang *et al.,* 2022).

Although the use of the BMFs can help to increase the yield of beans (Meng *et al.,* 2021), their use in Tanzania is very limited due to lack of awareness. These mulch films in the country are mostly used by research institutes, big agricultural companies and estates where the use is concentrated in horticultural crops . A little is known about the performance of the BMFs in field crops including common beans production. This on-station study intended to study the effects of BMFs in beans production while comparing it with commonly used cereal and leguminous dead mulches so as to find the possibilities of improving production of this important crop in Tanzania.

Materials and methods

Description of the study area

The study was conducted at SUA model training farm which is found at Sokoine University of Agriculture, Edward Moringe campus, Morogoro. The farm is located around latitude -6.848104°S and longitude of 37.655291°E. The area has an average annual temperature of 27°C and annual rainfall ranging from 800 mm to 1000 mm.

Field experiment

Two different experiments each with three replications and four traetments were conducted using completely randomized block design. In the first experiment, the treatments were BMF, pimento grass, maize straw and control. In the second experiment the treatments were BMF, butterfly pea, maize husks, and control. No any type of mulch was applied in control plots.

The plots size was 1.7 m x 1.3 m separated by 0.5 m space while distance between blocks was 0.8 m. Dead mulches were put manually to their respective plotswhile the biodegradable mulch films were spread over their respective test plots, fastened and buried at the edges using soil layer. Holes of 5 cm depth were made by using a sharpened peg of wood nature for plots which had control, pimento grass and straw mulch as treatments. For plots with biodegradable mulch a sharp razor was used to cut T shaped marks and holes were made using pointed stick with a great care to avoid destruction. Two seeds of Bush 59 bean variety were sown per hole in a spacing of 30 cm x 20 cm and covered with soil. Throughout the course of production management practices such as irrigation, pesticide application and fertilization were carried out uniformly among the treatments.

Data collection

Data collection was carried out from each plot from 9 samples. The 9 samples were selected randomly after excluding the guard rows. They were then tagged and subsequent data was collected from the tagged plants.

Germination percentage was collected for first 10 days. Leaf length, plant height and number of leaves were collected once per week until pod setting stage. Calculation of percent gemrination was based on the 9 representative rows where 100% germination would be 18 germinated common beans plants.

Weed population density was recorded by setting up two square quadrants of 0.25 m2 per each plot and weeds within the quadrants were physical counted.

For yield components, number of pods per plant at physiological maturity stage were counted and total weight (kg) of bean seeds from each plot were weighed after harvest. Grain bean yield in grams (g) was converted into tons per ha (t ha^{-1}) by using equation 1 below:

$$Grain\ bean\ yield\ (t\ ha^{-1}) = \frac{Grain\ bean\ yield\ (g) \times 10^{-2}}{0.24} \quad (1)$$

The actual harvest area was = 0.6 m x 0.4 m = 0.24 m^2

Statistical data analyses

The data collected was analyzed for the effects of treatments to experimental units by Analysis of variance (ANOVA) in GENSTAT statistical computer software as per randomized complete block design. The significant means were separated by Least Significant difference (LSD) at 5% level of significance.

In assessing germination rates, number of pods per bean plant and bean grain yield the fixed main effect was only the mulching options, whereas replicate blocks were treated as random effect. A ONE–WAY (ANOVA) was performed and the factor effect model is as in Equation 2.

$$Y_i = \mu + \alpha_i + \varepsilon_i \quad (2)$$

Where Y_i is the observed response variable in the ith factor; μ is the overall (grand) mean; α_i is the main effect of the factor mulching options; ε_i is the random error associated with the observation of response variable in the i^{th} factor.

Results

Effect of mulching options on bean germination

In the first experiment, germination in BMFs was statistically lower than the rest of the treatments while the control plot had the highest germination percent (Table 1). Results also showed that there was no significant difference in germination between plots treated with pimento grass and maize straw mulch. The highest rate of germination was observed at plot with control followed by plots treated pimento grass and maize straw mulch and the least rate was observed plots treated with biodegradable mulch.

In the second experiment, the highest germination was also observed in control plot with the maize husks being the last (Table 2). The sequence was: control, followed by butterfly pea then BMF and the least germination percent was observed in plot treated by maize husks.

Effect of mulching options on bean plant height

In experiment one, bean plant height was significantlty higher in control compared to the mulched treatments (Table 1). Bean plant height in BMFs was statistically higher than in maize straw, but not significantly higher than in pimento grass. The height in pimento grass mulch was also significantly higher than in maize straw. The highest bean plant height was observed at control plots followed by plots with BMFs, with pimento grass and the least height was observed at plots with maize straw mulch.

In the second experiment, control treament plant height was significantly higher compared to the mulched treatments, with BMF plant heights being sigficantly higher than maize husks and buterfly pea mulches (Table 2). The highest plant height was observed in control of experiment which was not treated with any kind of mulch followed by that treated with BMFs, maize husks and the least was the butterfly pea.

Effect of mulching options on number of leaves per plant

The number of leaves in plots treated with BMFs was statistically higher than the rest of the treatments in the first experiment (Table 1). Number of leaves in both pimento grass and maize straw mulches were not statistically different to the control. The highest number of leaves per plant was observed at plots treated with biodegradable mulch, followed with those treated with pimento grass, maize straw mulch and control. The same trend was observed in weekly collected data (Fig. 1).

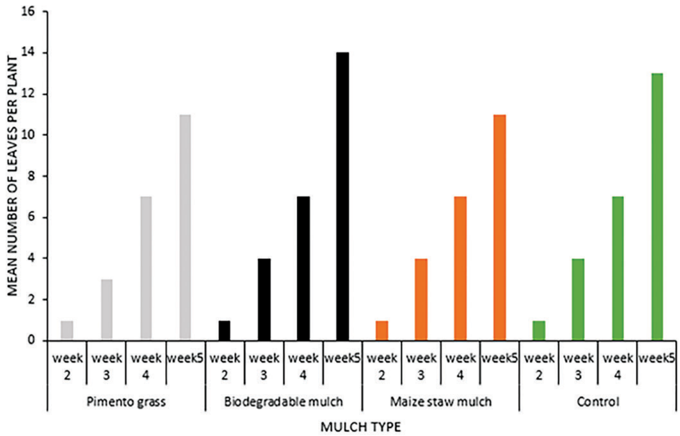

Figure 1: Weekly number of leaves per plant in different mulching options in experiment 1

In the second experiment, the number of leaves were signifcantly higher in the control treatment compared to the rest of the treatments (Table 2). The BMFs had significantly higher number of leaves than maize husks and butterfly peas mulches, but not significantly different with the control.

Effect of mulching options on number of branches per plant

In the first experiment, there was statistically higher number of branches per bean plant in BMFs and control treatments as compared to pimento grass and maize straw mulches (Table 1).

In the second experiment control had significantly higher number of branches than the rest of the treatments. The number of branches did not differ significantly among BMFs, maize husks and butterfly pea mulches (Table 2).

Effect of mulching options on number of weeds per plot

In the first treatment, all treatments were statistically different to each other, with highest number of weeds observed in the control (Table 1). The highest number of weeds per plot was observed in control plots, followed by those treated with pimento grass, maize straw and the least number of weeds was observed at plots treated with BMFs. the number of weeds kept increasing with increase in number of days after germination (Fig. 2).

Like in the first experiment, in the second

Table 1: Summary results of growth performance of common bean under different mulch types in experiment 1

Mulches	Germination (%)	Plant height	Leaves per plot	Branches per plant	Weeds per plot
Pimento grass	95ab	36.0b	6b	3b	23b
BMFs	92b	36.5b	7a	4a	4d
Maize straw	95ab	34.2c	6b	3b	11c
Control	98a	37.9 a	6b	4a	50a
s.e.d.	1.43	0.498	0.1394	0.1123	1.389
L.S.D. (0.05)	3.51	1.219	0.3411	0.2747	3.4
P –value	0.026	0.002	<0.001	<0.001	<0.001
C.V. (%)	1.8	1.7	2.6	4.1	7.8

Key: *C.V. = coefficients of variation; LSD = Least significant differences of means; s.e.d. = Standard errors of differences of means. Means in each column bearing different letter(s) differ significantly at 5% error rate; otherwise, are not statistically different.*

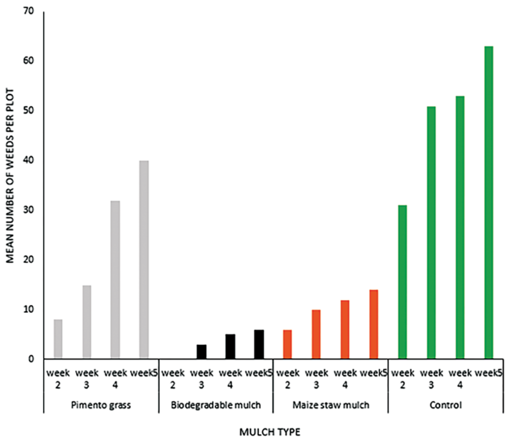

Figure 2: Number of weeds per week in different mulching options in Experiment 1

experiment, control was having significantly higher amount of weeds, while the BMF was having significantly the lowest amount of weeds compared to all the treatments (Table 2). The ranking was: control followed with that treated with butterfly pea mulch, maize husks and lastly BMF.

Table 2: Summary results of growth performance of common bean under different mulch types in experiment 2

Mulches	Germination (%)	Plant height (cm)	Leaves per plant	Branches per plant	Weeds per plot
BMFs	93ab	34b	7a	3b	3d
Butterflypea	94ab	31c	5b	3b	18b
Maize husks	90b	32bc	5b	3b	6c
Control	98a	37a	8a	4a	39a
L.S.D.(0.05)	6.14	1.77	0.86	0.57	1.79
P -value	0.092	<0.001	0.002	0.014	<0.001
s.e.d.	2.509	0.72	0.35	0.23	0.73
C.V. (%)	3.3	2.7	6.7	9.4	5.5

Key: *C.V. = coefficients of variation; L.S.D. = Least significant differences of means; s.e.d. = Standard errors of differences of means. Means in each column bearing different letter(s) differ significantly at 5% error rate; otherwise, are not statistically different*

Effect of mulching options on number of pods per plant

In the first experiment, the number of pods was significantly higher in BMFs compared to other treatments (Table 3). The number of pods were not significantly different between control, pimento grass and maize straw treatments. Like in the first experiment, the number of pods was significantly higher in BMFs and lowest in control the second experiment (Table 4)

Effect of mulching options on grain bean yield

In the first experiment, the grain yield in BMFs was significantly higher than any of the other treatments. The grain yields in other treatments were not significantly different to each other Plots with biodegradable mulch had the highest grain bean yield (11.8 t ha^{-1}) followed by plot with control (6.3 t ha^{-1}), maize straw mulch (5.8 t ha^{-1}) and the least grain bean yield was plot with pimento grass (5.1 t ha^{-1}). From the second experiment the grain yield in BMFs did not differ significantly with that from maize husks (Table 4). However, the grain yield in BMFs was significantly higher than in control and in butterfly pea mulch

Discussion

For most growth and yield parameters the use of BMFs proved to be better compared to other treatments except in term of percentage germination. In percentage germination the plots with control had the best performance. This could be attributed to cover caused by mulches which might have affected the amount of solar radiation reaching the seeds. Zhou *et al.* (2005) report that germination of seeds is promoted by exposure to sunlight. Apart from

Table 3: Summary results of number of pods and grain yield of common bean under different mulch types in experiment 1

Mulches	Pods per plant	Bean grain yield (t ha^{-1})
Pimento grass	13b	5.1b
BMFs	21a	11.8a
Maize straw	13b	5.7b
Control	14b	6.3b
s.e.d.	0.61	0.51
L.S.D. (0.05)	1.49	1.25
P –value	<0.001	<0.001
C.V. (%)	4.9	8.7

Key: *C.V. = coefficients of variation; L.S.D. = Least significant differences of means; s.e.d. = Standard errors of differences of means. Means in each column bearing different letter(s) differ significantly at 5% error rate; otherwise, are not statistically different.*

Table 4: Summary results of number of pods and grain yield of common bean under different mulch types in experiment 2

Mulches	Pods per plant	Grain yield (t ha^{-1})
BMFs	20a	9.8a
Butterflypea	16bc	6.2b
Maizehusks	17b	8.5a
Control	13c	5.1b
L.S.D.(0.05)	3.034	1.87
P–value	0.006	0.003
s.e.d.	1.24	0.76
C.V. (%)	9.2	12.6

Key: *C.V. = coefficients of variation; L.S.D. = Least significant differences of means; s.e.d. = Standard errors of differences of means. Means in each column bearing different letter(s) differ significantly at 5% error rate; otherwise, are not statistically different.*

low performance in BMFs, maize straws and maize husks mulches also performed relatively poorly in seed germination. Thick nature of these mulches could physically hinder penetration of a shoot of germinating seed.

BMFs has also demonstrated superiority in growth performance indicators. These included number of branches, number of leaves and plant heights. These could be linked to the effect the BMF has shown in weed control as compared to other treatments including the control treatment. Plants freed from weed competition and moisture stress perform better than those subjected to such stresses (Yin *et al.,* 2019). Mehmood e*t al.* (2018) reported similar results that application of mulch showed a maximum reduction in weed density, fresh and dry weed biomass and suggested that organic mulches such as dry leaves and straws could be used for effective weed control.

For the case of yield, biodegradable mulch had performed better as plants in plots treated with it had large number of pods per plant and also the grain bean yield was high. This could be attributed to the BMFs relative superiority in moisture conservation and weed control (Ossom, 2005; Jodaugiene *et al.,* 2006; Jia *et al.,* 2020).

Conclusion

This on-station experiment has indicated that BMFs performs better than dead mulches except in germination. Care need to be taken to improve germination by making sure the mulch film does not impede a germinating plant. Given advantages of BMFs over the plastic synthetic mulches including faster biodegradability and safe incorporation to the soil in the next season, there is a bigger potential for expansion of it uses. However, on field studies need to be done in different agroecological zones to establish its behavior as well as it rate of degradability. Studies on cost effectiveness and affordability also need to be done in order to predict the potential for adoption.

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