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Research paper

Effects of relay cover crop planting date on their biomass and maize productivity in a sub-humid region of Zimbabwe under conservation agriculture

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ABSTRACT

Relay cropping of cover crops is a strategy of increasing biomass yields and productivity of maize-based systems. However, there is need to strategically plan the relay cropping to avoid competition between the main crop and the relay cover crops while at the same time obtaining optimum yields from both crops. A study was carried out in a clay soil in a sub-humid region of Zimbabwe to investigate the effect of introducing different relay cover crops at 8, 11 and 15 weeks after planting maize (WAPM) into a standing maize crop on biomass yield of the relay cover crops, their emergence and maize yields in the 2012–13 and 2013–14 seasons. From the results of the study, it was observed that the introduction of relay cover crops late in the season compromises their emergence and hence biomass yields (as low as 0.8 kg ha^{-1} for blue lupins (*Lupinus angustifolius* var. *angustifolius* (L.)). In a season where longer mid-season dry spells were experienced (2013–14), biomass yields of the relay cover crops were lower than in 2012–13 season. Delays in planting of relay cover crops (i.e. from 8 to 11 and from 11 to 15 WAPM) resulted in yield reductions of around 50%. Relay cover crops introduced at different periods of the season had no significant effects on maize grain and biomass yields. However, there are relay cover crops such as the velvet bean (*Mucuna pruriens* (L.) DC) and common oats (*Avena sativa* L.) that showed better emergence even in the sub-optimal conditions (with emergence as high as 90%). Of all the investigated relay cover crops, none could contribute to significant amounts of biomass thus insignificant increases in total plot biomass. There is need to investigate on other earlier planting dates that do not compromise the biomass productivity of such relay cover crops.

1. Introduction

Conservation agriculture (CA) has been promoted as a crop production strategy that help alleviate food shortages while conserving the environment e.g. Thierfelder et al. [1]. Conservation agriculture has three principles, which are minimum soil disturbance, diversification of crops and permanent soil cover by the use of crop residues [2]. However, the smallholder set-up of Zimbabwe is characterised by the integration of crops and livestock [3]. The general arable land holding capacity for smallholders is less than 2.5 ha and an average of 4 herd of cattle per household [4]. On this arable land, smallholder farmers can only produce an average of 1 t ha^{-1} of maize biomass due to limited resources and climatic variability [5]. For farmers practicing CA, retention of plant biomass of a minimum of about 2.5 t ha^{-1} is recommended to attain at least 30% ground cover while farmers are producing less than the desired in some cases [6]. On the other hand, most parts of the country experience a long dry off-season period. It is during this dry period that livestock face reduced grazing options hence, making maize residues a good option to feed the livestock [3]. This, thus bring a trade-off competition for the use of maize residues between retaining them in the field to maintain ground cover and feeding livestock [3,7,8]. This thus calls for strategies to increase biomass production while at the same time maintaining or improving crop productivity. One

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Table 1
Top soil properties (0–10 cm) at University of Zimbabwe.

Soil property	UZ farm
Soil depth (cm)	0–10[a]
Soil organic carbon (g kg^{-1})	1.68[a]
Soil pH ($CaCl_2$)	5.1[a]
Clay content (g kg^{-1})	400[a]
Sand content (g kg^{-1})	270[b]

[a] Source: Nyamapfene, 1991 [16].
[b] Value from lab analysis.

option is the practicing of intercropping with the integration of cover crops as intercrops in maize-based systems. Intercropping refers to the simultaneous production of two different crops on the same area of land [9]. Intercropping involves relay cropping which is the introduction of another crop at a certain growth stage of the first crop aimed at minimizing competition between the two crops while increasing productivity of the whole system [10]. Relay cover crops (cover crops introduced at a later stage of the first crop) may be introduced in cropping systems at different growth stages of the main crop depending on their roles. If the relay cover crops are leguminous, they supplement nitrogen into the system from fixation achieved through symbiotic relationships with rhizobial bacteria [11]. In a study carried out by Jeranyama et al. [12] in sub-humid Zimbabwe, relaying of cowpea (*Vigna unguiculata* L.) twenty-eight days after planting the maize improved the yield by 20% of the subsequent maize crop following the maize-cowpea intercrop. Due to their high potential biomass productivity they can aid to more biomass in the system thus reducing competition on maize [9]. The study by Jeranyama et al. [12], cowpea yielded biomass yields of 3000 kg dry matter ha^{-1} which is a significant addition to the system. However, the success in the production of the relay cover crops depends on the availability of adequate moisture to meet the need of both crops [13]. Thus, if introduced too early, the relay cover crops may lead to competition with the main crop [9] and on the other hand, if introduced too late in the season, their growth and development may be compromised by unfavourable conditions (low moisture levels and reducing temperatures) late in the season [14]. There is need to identify suitable planting dates for the relay cover crops that does not compromise the yields of either the main crop or the relay cover crop. The possibility of relay cover crops has been reported for the drier regions of Zimbabwe [15] but information from the sub-humid area is sparse.

This study thus, assesses the effects of relay cropping different cover crops at different dates on their biomass productivity and on companion maize productivity in a maize (*Zea mays* L.)-based farming system in a sub-humid region in Zimbabwe.

2. Materials and methods

2.1. Site description

The study was conducted at University of Zimbabwe farm (UZ) (17.73 ° S; 31.02 ° E). The soil at UZ is classified as a *Chromic Luvisol* [16] with 40% clay content (Table 1). The site has an altitude of 1503 m above sea level (masl) and daily maximum temperatures reach 31 °C. It lies in Zimbabwe agro-ecological region II [17] and receive rainfall in a unimodal pattern amounting between 800 and 1000 mm (Fig. 1). Zimbabwe agro-ecological region II is also characterised by crop and livestock production [18].

2.2. Description of experiment

The experiment commenced in the summer growing season of 2012–13 to determine the effects of planting dates of the relay cover crops on their emergence (2012–13) and biomass production and maize productivity in the 2012–13 and 2013–14 seasons. The experiment was set as a 6 × 3 + 1 factorial in a randomized complete block design with four blocks and the first factor was the relay cover crop species, which had seven levels:

1. Sole maize (control) planted at 90 cm between rows and 25 cm between plants to achieve a plant population of 44,444 plants ha^{-1}.
2. Velvet bean (*Mucuna pruriens* (L.) DC) planted in-between maize rows at 25 cm between plants to achieve a plant population of 44,444 plants ha^{-1}.
3. Fish bean (*Tephrosia vogelii* Hook. f.) planted in-between maize rows at 50 cm between plants to achieve a plant population of 22,222 plants ha^{-1}.
4. Blue lupin (*Lupinus angustifolius* var. *angustifolius* (L.)) planted in-between maize rows at 50 cm between plants to achieve a plant population of 22,222 plants ha^{-1}
5. Hairy vetch (*Vicia villosa* Roth.) broadcast in-between maize rows at 60 kg ha^{-1} aiming at plant population of 44,444 plants ha^{-1}
6. Common oats (*Avena sativa* L.) broadcast in-between maize rows at 60 kg ha^{-1} aiming at plant population of 44,444 plants ha^{-1}
7. Rhodes grass cv Katambora (*Chloris gayana* Kunth) broadcast in-between maize rows at 30 kg ha^{-1} aiming at plant population of 44,444 plants ha^{-}1

The second factor was time of planting the relay cover crop into the standing maize crop; the three times were:

1. Eight weeks after planting maize (WAPM) (9 WAPM in 2013–14 season)
2. Eleven WAPM (12 WAPM in 2013–14)
3. Fifteen WAPM (16 WAPM in 2013–14).

Maize in all treatments was planted at 90 cm between rows and 25 cm between plants to achieve a plant population of 44444 plants ha^{-1}. Planting of maize was done by placing seed into basins created with hand hoes and received fertilizer at the rate of 165 kg ha^{-1} Compound D (i.e. 11.6 kg ha^{-1} N, 10.1 kg ha^{-1} P and 9.6 kg ha^{-1} K) applied at seeding and 200 kg ha^{-1} AN (i.e. 69 kg ha^{-1} N) split applied at 4 and 7 weeks after emergence. In the 2013-14 season, the relay cover crops were introduced a week later because of delays in adequate rainfall for planting. Plot size measured 3.6 m (4 rows) × 4.5 m and harvesting was done from net plots that measured 1.8 m (2 rows) × 3.5 m. Both the maize and the relay cover crops were grown under rain-fed conditions with residues being retained in their respective plots. At the start of the experiment, maize residues were spread uniformly in all the plots at the rate of 3 t ha^{-1}.

No basal fertilizer or top dressing was applied to the legumes in all seasons. The relay cover crops were planted into either holes or lines created using a hand hoe in both seasons. In the 2013–14 season, fish bean and blue lupin seed were pre-treated to improve their germination. Fish bean seeds were soaked for 24 h in water taken off the boil and then seeded and blue lupin seeds were soaked for five minutes in water taken off the boil prior to seeding. Maize variety Pristine 601, a medium maturing commercial hybrids that takes approximately 135 days (19 weeks after planting) to reach full maturity, was planted across all plots in both seasons. In both seasons, glyphosate [*N*-(phosphono-methyl) glycine] was applied as an initial weed control measure at seeding of the maize crop at both sites at the rate of 2.5 l ha^{-1} (i.e. 1.025 l ha^{-1} active ingredient). This was followed by manual weeding whenever weeds were 10 cm tall or 10 cm in length for weeds with stoloniferous or rhizomatous growth habit (i.e. three weedings per season). Maize was harvested at maturity and the relay cover crops were harvested at the same

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