Effects of different mulches on the yield and productivity of drip irrigated onions under tropical conditions

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ABSTRACT

There are still a lot of gaps in knowledge on how different types of mulch from organic sources can be used to improve the sustainability of irrigated onion production; and this requires further investigation. An experiment was therefore set up at the Savannah Agricultural Research Institute Tamale, Ghana, to investigate the influence of mulching with different straw materials, on the yields and productivity of onions, variety ‘White Creole’. The trial comprised three treatments: No Mulch (T1), mulching with Andropogan grass straw (T2) and mulching with rice straw (T3) at three tonnes per hectare each. The experiment was conducted from April to mid-July 2010 (dry season) and repeated between February and May 2011, both under drip irrigation. The soil of the experimental field was categorised as sandy loam, with pH 5.8. The results of the trial indicated that different types of organic based mulch such as grass and rice straw could contribute significantly to improved onion productivity and yields under tropical conditions. Onion bulb yield of T2 (10.58 t·ha⁻¹) was significant (P<0.05) and over 60% higher than T3 (6.63 t·ha⁻¹); and over 230% greater than T1 plot yields (3.20 t·ha⁻¹). Analysis of the economic returns of the mulching technologies revealed a benefit-cost ratio of 2.31 and marginal rate of returns of 140 for T2, suggesting that this technology is dominant over T3 or T1 technologies and is therefore recommendable to irrigated onion farmers.

INTRODUCTION

Mulching of agricultural fields with stones or organic materials is an agricultural strategy that dates back beyond ancient Egypt. For more than a thousand years, mulching has been used in several parts of the world to evade drought and increase crop yield (Dale and Lightfoot, 1996). The practice of mulching has been utilised to great advantage in the development of horticultural crops (Smolikowski et al., 2001; Meyer et al., 1970) and has been proven to significantly improve the growing conditions of vegetables grown in the tropics, including onions (Coleo et al., 1996; Abdal et al., 2000; Abu-Rayyan and Abu-Imraileh, 2004).

Mulch is any material placed on the soil surface to conserve moisture, lower soil temperatures around plant roots, prevent erosion and reduce weed growth. Mulches can be derived from either organic or inorganic materials (Meyer et al., 1970; Smolikowski et al., 2001; Rumpel et al., 2003). Mulching does not perform instant miracles, but it encourages better plant growth and development. These benefits accrue whether plants are growing in the coolest mountain conditions in Vietnam, the hot humid
conditions in the Philippines, or the hottest climatic conditions of desert Kuwait (Abdal et al., 2000; Erenstein, 2003; Damasa and Lovereal, 2005; Castella et al., 2006). Mulching in vegetable production is often cited as a good agricultural practice (GAP). GAPs are “practices that address environmental, economic and social sustainability for on-farm processes, and result in safe and quality food and non-food agricultural products” (FAO-COAG, 2003; White et al., 2005). The principle also underlines improving natural resources (e.g. water and land) use among others (Anderson, 1991).

Thus, a key advantage of mulching is that it reduces water use by up to 75% as it protects the soil from evaporation. Problems associated with mulching include:

1. It offers cover for small slugs, which can be devastating on crops such as peas and carrots;
2. It can be unsuitable for crops that need fine sandy soil to flourish (for example, carrots) or are subject to collar rot in moist conditions (for example, garlic); and
3. Mulching with plastic film has been reported to cause extreme increase in soil temperature during the summer months in sub-tropical areas (Knowler and Bradshaw, 2007; Erenstein, 2003).

In recent years, a lot of work has gone into the study of the effects of different plastics as mulch in the production of crops including vegetables. Cecil (1989) demonstrated that the use of different mulching materials such as plastic, rice husk and Andropogan grass improved yam tuber yields in the Northern Region of Ghana. Mulching with coloured plastic for example, has been investigated as a means of discouraging thrips on leeks (Haim and Lesley, 2002).

As a spice or condiment, onion is universal in most African dishes, served as a stew, soup, or 'pepper sauce'. In 2012, the land area of onion planted in Ghana was in excess of 15,000 ha (SRID, 2012), yet the country had to import more than half of her requirements (over 5 million US Dollars (USD) worth of the spice from Burkina Faso and Niger alone), due to under production in the major growing areas that is the Guinea Savannah agro-ecological zone (GSZ) of Northern Ghana (GNA, 2012). According to the Ghana Agricultural Producers and Traders Organization (GAPTO) conditions abound in Ghana for the large scale production and possible export of the commodity.

The vegetable growing season (November-May) in Northern Ghana is characterised by very high day and night temperatures (especially April-May) (CSIR –SARI, 2009). Several workers have underscored that “temperature controls the development and performance of the onion plant in all its growth stages” (Brewster, 2008; Ansari, 2007; Abu-Rayyan and Abu-Ilmaileh, 2004; Coolong and Randle, 2003). Thus, coupled with high rates of evapo-transpiration, these high temperatures have been cited as major contributory factors to the declining yields of irrigated vegetables including onions in the major vegetable producing areas of Ghana (Tanzubil et al., 2004). Within this period, however there is abundance of Andropogan grass and rice straw (from recent harvests of the crop) that could be used as mulching material to address this situation. It was therefore found necessary to evaluate how these different types of straw when utilised as mulch will influence the yields and productivity of irrigated onions under conditions of the Guinea Savannah agro-ecological zone of Northern Ghana. An experiment was therefore set up to investigate the influence of grass and rice straw mulching on the yields and productivity of drip irrigated onions, variety ‘White Creole’.

MATERIALS AND METHODS

Study area

The field experiments were conducted at the Council for Scientific and Industrial Research -Savannah Agricultural Research Institute (CSIR-SARI), the Technology Park of the International Centre for Soil Fertility and Development (IFDC), at Nyankpala, Ghana (latitude 9° 25 N, longitude 0° 58 W and altitude 183 m above sea level). The trials were conducted from April to mid-July 2010 (dry season) and repeated between February and April 2011, under drip irrigation. The experiment was established in a sandy loam soil with pH 5.8. The field had previously been treated with 3 t·ha⁻¹ of well decomposed organic fertilizer (cow dung). The trial area was a newly developed area for the IFDC Technology Park and had not been previously put to any crop.

Preparation of plants

The experimental materials comprised onions, variety “white Creole”. 20 g of onion seed was drilled in rows in two wooden nursery boxes containing a soil-less medium of well cured compost from rice husk, saw dust and poultry manure four weeks prior to the start of each planting season. Nursery wooden boxes (150 × 90 × 60 cm) were fertigated manually daily, with a watering can containing a solution of: 15N-15P-15K (300 g) and ammonium nitrate (100 g) dissolved in 100 L of water. From 0–10 days after planting (DAP), irrigation was 1500–2500 mL box⁻¹. This was increased to 2500–3000 mL box⁻¹ from 11 to 25 DAP. Nine small holes were drilled at the bottom of each box to facilitate drainage of excess water. Five days prior to transplanting time, seedlings were ‘hardened’, by exposing them to more direct sunshine and reducing the watering regime by half.
Four weeks after germination, seedlings were transplanted to ‘permanent’ trial plots in the Technology Park. The trial was managed under a full drip irrigation regime. The irrigation system comprised of a low pressure (0.40 Bar) drip arrangement of two lines per bed and 60 cm apart. Each bed had two rows or dripper lines with the spacing between lines and emitters being 0.60 × 0.30 m. The system used is a product of Dizengoff Co. Limited, the sole dealers of this equipment in Ghana. The trial area comprised of raised flat beds 23 × 1.0 m. Each dripper (emitter) had two seedlings planted on the inner and outer sides, 30 cm from each other.

The mulching materials were Andropogan ssp grass straw and rice (*Oryza sativa* L.) straw. Each replication comprised three treatment plots each 7.2 × 1.0 m occupying a whole bed of size 23 × 1.0 m. Plants were mulched with straw, 0.25–0.30 cm thickness over the flat beds, evenly covering the drip lines on the beds. Roughly, 6.0 kg dry straw was required for mulching each bed of 23 m² area. The mulching was carried out after first soil ‘stirring’ (weeding by hand hoe) and basal fertilizer application.

All treatments were fertilized three times. Compound fertilizer 15N-15P-15K was applied as basal fertilizer three weeks after transplanting at a rate of 30 kg NPK-ha⁻¹. Sulphate of ammonia was applied as top dressing six weeks after transplanting at a rate of 30 kg N-ha⁻¹. Proven best agronomic practices for onion production were applied in both seasons of the trial as recommended for onion cultivation under irrigation system in Ghana (GIDA-JICA SSIAPP FU, 2004). Figure 1 depicts the trial area for onions with different types of mulch under drip irrigation at the IFDC Technology Park at, SARI, Nyankpala in the Northern region of Ghana.

**Experimental measurements and statistical analyses**

The trial comprised three treatments (T): No Mulch (T1), mulching with Andropogan grass straw (T2) and mulching with rice straw (T3), randomly assigned on each bed and replicated three times. Biological data collected for the trial included: plant height at 7 weeks after transplanting (cm), number of leaves, bulb diameter, bulb weight (g), days to 50% toppling (physiological maturity) and yield (t-ha⁻¹).

The collected data were analyzed following Fisher’s analysis of variance technique and treatment differences were compared for significance by applying the least significant difference (LSD) test at 0.05 probability level (Steel and Torrie, 1984). In addition, data on cost of inputs and market prices of onions (from surveys) were also collected for economic analysis of the outcome of the trials. Partial budgets were constructed for each of the trial outcomes. Key indicators estimated included total variable costs (TVC), marginal cost (MC), gross benefit (GB), benefit cost (B-C) ratio and marginal rate of returns (MRR). The total variable cost was the estimated cost of operations including the cost of labour for all the field activities and other agro-inputs such as fertilizers. Gross benefit was estimated as the difference between total revenue from the sale of harvested onion and TVC. It represents the returns to factor inputs without the cost of fixed inputs. Benefit cost ratio was estimated as the ratio between the gross benefit and TVC. It represents the
returns to every unit of investment. Marginal rate of returns was also estimated as the ratio between the differences in the cost of the investment (CIMMYT, 1988; Anandurup, 1984).

**RESULTS**

The results of the two seasons’ work were collated (since preliminary analyses did not yield significant cultivar by year interaction) and are presented in Table 1.

In Table 1, plant height of onions (variety White Creole) was highest in the T2, followed by the T3; both of which were significantly higher (P<0.05) than the control treatment (T1).

As far as leaf count was concerned, the number of leaves in all three treatments did not differ significantly (P<0.05) from each other, although the T2 still produced more leaves per plant than in the other treatments. In a similar vein, in bulb diameter, bulb weight, 50% flowering and yield of onions T2 was higher than the others. Bulb size of onions was measured as the mean of two cross sectional dimensions (diameters) taken for ten bulbs. The biggest bulbs were obtained when the onions were mulched with grass and they were significantly (P<0.05) bigger than those in the other treatments. This was followed by T3 which was not significantly different from the control (T1).

Estimate of onion maturity can be taken at ‘days to 50% toppling’ (neck fall stage) of the bulbs. Once senescence of the plants growth cycle is estimated to have set in, and in one or two weeks after this, the onion crop could be ready for harvesting. Close to 90 days in ‘days to 50% toppling’ was recorded for grass mulched onions and the lowest days of this maturity index of 75 days was noted for the T1, or no mulch treatment.

The yield of T2 (10.58 t-ha⁻¹) was significantly higher than those of the other treatments. Indeed it was 60% higher than T3 and over 230% higher than T1 plots.

**DISCUSSION**

**Agronomic parameters**

Significant increases in bulb yield and other agronomic parameters of onions observed in the trials is a phenomenon frequently associated with mulching (Erenstein, 2003; Hanada, 1991). Castella and Quang (2006) and Haim and Lesley (2002) have reported that vegetables experience enhanced growth and development as a result of utilising organic or so called summer mulches, since most of the advantages of such mulches are realized in hot weather. The mechanism of mulch activity may be summed up in the following: Mulches protect the soil from compacting rains, foot traffic, drying winds, and heat. The mulches help to control weed proliferation (by excluding light from germinating seedlings) thereby reducing competition for light, water, and nutrients. The resulting fewer cultivations mean less crop-damaging root pruning (Hanada, 1991).

By reducing the loss of soil moisture, mulches lessen the frequency of necessary watering, and the vegetable suffers less in dry spell periods. Organic mulches also increase the water absorption rate of soils. The reduced soil temperatures under organic mulches encourage root growth in the upper soil layer where there is more oxygen and fertilizer. The mulch reduces the splattering of soil on vegetable leaves and fruit during rains or sprinkling. This can reduce losses due to soil-borne diseases (Steiner et al., 1998; Derpsch, 2001; Westerfield, 2013).

**Bulb size (diameter) and bulb weight**

The biggest bulbs were obtained when the onions were mulched with grass and bulb size under this treatment was significantly larger than in the other treatments. It is apparent that the large size of bulbs translated into heavy bulbs (and enhanced yield). The bulb weight of the mulched treatments were all significantly (P<0.05) greater.

**Table 1.** Effects of different mulches on the agronomic parameters and mean yields of drip irrigated onions for combined two production cycles.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant height (7 WAT) (cm)</th>
<th>Number of leaves</th>
<th>Bulb diameter (cm)</th>
<th>Bulb weight (g)</th>
<th>Days to 50% Toppling</th>
<th>Yield (t-ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No mulch</td>
<td>46.302</td>
<td>8.99</td>
<td>5.07</td>
<td>65.70</td>
<td>77</td>
<td>3.20</td>
</tr>
<tr>
<td>Grass straw</td>
<td>49.079</td>
<td>9.80</td>
<td>5.71</td>
<td>175.16</td>
<td>88</td>
<td>10.58</td>
</tr>
<tr>
<td>Rice straw</td>
<td>49.810</td>
<td>9.47</td>
<td>5.24</td>
<td>139.42</td>
<td>83</td>
<td>6.63</td>
</tr>
<tr>
<td>LSD 0.5</td>
<td>2.57</td>
<td>1.25</td>
<td>0.45</td>
<td>40.55</td>
<td>1.98</td>
<td>2.52</td>
</tr>
<tr>
<td>SE</td>
<td>1.236</td>
<td>0.599</td>
<td>0.2163</td>
<td>19.498</td>
<td>0.951</td>
<td>1.212</td>
</tr>
</tbody>
</table>
than the control, with the grass mulch treatment being highest.

Field observations during the trials indicated that Andropogan grass as mulch was more 'stable' on the onion beds and spread more compactly and uniformly than the rice straw mulch and was thus more effective mulch in this regard. More active vegetative growth of the grass straw treatment onions, in comparison to the rice straw one may have led to enhanced bulb size and weight as more assimilates were translocated into bulb formation than in the other treatments. Anisuzzaman et al. (2009) demonstrated that mulching enhances the development and size all the agronomic parameters of onions.

**Days to 50% toppling**

Mulching with organic material, such as grass, clearly prolonged days to maturity in onion production in the two cycles of production in this work. A number of researchers have demonstrated that mulching with materials such as grass straw, compared to the other treatments, such as, no mulching, helped to create a more conducive soil micro-environment for the onion plant to grow and develop more fully (Hanada, 1991; Riley et al., 2003). Kawaguchi (1974) and Lament (1993) however both reported otherwise for plastic mulching. The latter reported early harvest of onions by polythene mulching while Lament reported that black plastic mulch can result in 2–14 days earlier harvest of vegetables as against clear plastic mulching which can result in 21-day earlier harvest.

**Yields**

Onion yields in all three treatments were significantly (P<0.05) different from one another, with T2 onions characteristically producing the highest bulb yield of onions. Mulching with many types of organic materials, including chopped grass and clover material has been demonstrated to positively contribute to improved plant growth, development and enhanced bulb yield of onions (Russo et al., 1997; Hanson et al., 2001; Hugh et al., 2003; Riley et al., 2003). Further, earlier researchers have demonstrated that in comparison to unmulched soils, the crop yields of mulched soils (depending on factors such as geographic location, soil type and nature of mulch) can be enhanced two- or three-folds in vegetables (Stephenson and Bergman, 1963; Pollack et al., 1969; Bhella, 1986).

Knowler and Bradshaw (2007) and Hopps et al. (2008) and other researchers have corroborated the findings in this work which underscores that mulching irrigated vegetables with organic materials such as Andropogan grass is a critical strategy for enhancing and sustaining the productivity of small and medium onion cultivation in the Guinea savannah zone of Ghana.

**Economic considerations**

Figure 2 depicts the distribution of the costs of onion
production by mulching technology using data collected on cost of inputs based on market surveys. These results show that onion production in general is highly dependent on labour (skilled and semi-skilled). In other words, onion production can be described as a labour intensive business venture. Among the list of cost items for the onion production technology, labour alone accounts for more than 80% of the total cost of operations regardless of the technology. The remaining 20% of the cost is distributed among the costs of fertilizers, seeds, bags and fungicides in that order (Figure 2). The cost structure of the trials indicates that a potential user of the mulching technology requires additional investment of 7931.60 Ghana cedis (GHc) per hectare and GHc 8001.60 per hectare for rice straw and grass straw, respectively. The extra cost is associated with two main reasons. First, an investor will have to pay for the cost of mulch materials used on the field. Due to the recorded increase in yield, an investor will have to procure more bags for packaging the harvested onion (Table 2).

Although the total operations cost for grass straw was ranked first, the cost of mulch material from grass straw is GHc 9.00 less than mulch from rice straw. Overall, investment in any of the mulching technologies results in a reduction of the cost of producing a kilogram of onion. With rice straw, the cost of producing 1 kg of onion reduces from GHc 2.43 to 1.20. The cost further declines by about GHc 1.67 with the mulch from grass straw (Table 2).

Following the agronomic results, whereas the no mulch technology managed just to break even at GHc 236 per hectare gross margin, rice and grass mulching yielded very high returns of 8,643 and GHc 18,448 respectively, (Table 3).

The grass straw technology continues to dominate in terms of economic returns. The results revealed that for every kilogram of onion produced, the grass straw technology yielded GHc 0.74 as gross margin. In
addition, to every cedi invested, the grass straw technology resulted in 231% returns. Comparing this to the commercial lending rate in Ghana, a potential investor will not only be able to pay off the cost of investment, but will still make very good profit.

Further analyses indicate that an investor stands to gain from the adoption of any of the mulching technologies. The MRR suggest that an investor will obtain more than 100% returns from reallocating their resources from zero mulch to any of the mulching technologies. More specifically, if a farmer decides to invest GHC 1.0 meant for onion production under no mulch to rice straw mulch, he/she will gain about GHC 29 in returns. Similarly, the farmer will gain GHC 140 if he/she decides to reallocate GHC 1.0 from no mulch to grass straw mulching technology. Comparing the rice and grass straw mulching technologies, it is indicative that the Andropogan grass straw mulch is economically superior and therefore dominant over rice straw.

RECOMMENDATIONS AND CONCLUSION

All agronomic parameters recorded, including plant height, number of leaves, bulb width, bulb weight and yield were highest in the grass straw treatment and lowest in the no mulch one. The yield effect of mulching with grass straw was remarkable and significantly higher than in the other treatments.

Mulching in general, therefore contributed to improving the growth, plant vigour, yields and productivity of onion under drip irrigation. It will be recommended to use grass straw in particular, as mulching material in onions production for several reasons:

1. The dry grass compared to the rice straw, was much heavier and was not easily moved about by the wind, etc. Straw from grass also covered the onion beds more uniformly and thus provided (to a greater extent) the advantages of mulching such as conservation of soil temperature and moisture. Straw from rice on the other hand tended to be amorphous, fluffy and not very stable and permanent on the onion beds.

2. It is relatively cheaper to acquire a reasonable quantity of grass straw in the savannah area of Ghana than to obtain the same quantity of rice of any other material for the purposes of mulching since Andropogan grass grows abundantly in all places out of towns, in the rainy season. There is also more competition for rice straw for composting, bailing, bedding for cattle transport, etc than there is for grass.

Analysis of the economic returns of the mulching technologies suggests that the grass straw mulching is superior and thus dominant over rice straw mulching or no mulching technologies and is therefore recommendable to both small and medium holder onion farmers.

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REFERENCES


\(^{1}\)Lending rate (Agricultural Development Bank, Ghana) as at February 2013 was 30%.