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Effects of White Plastic and Sawdust Mulch on 'Savoy' Baby Cabbage (Br*assica oleracea* var. *bullata*) Growth, Yield and Soil Moisture Conservation in Summer in Swaziland

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Abstract: Mulches offer immense benefit in horticultural production, however their use has not been studied under local conditions. This study was carried out to determine the effect of white plastic and sawdust mulches on growth, yield of 'Savoy' baby cabbage (*Brassica oleracea*. var bullata), weed suppression and conservation of soil moisture on a loamy soil at Luyengo. A control where no mulch was applied was also included in the experiment. The results indicated that mulch type significantly ($p<0.05$) affected growth and yield of 'Savoy' baby cabbage, weed infestation and moisture conservation on a loamy soil. There was no significant difference in yield of cabbage heads from plots mulched with white plastic or sawdust while the control produced relatively the lowest yield of 'Savoy' baby cabbage. The results showed that both white plastic and sawdust mulches conserved moisture. When growing 'Savoy' baby cabbage during the warm season, it is recommended to mulch with white plastic or sawdust in order to realise near perfect growth and yield, as well to conserve soil moisture and weed suppression by white plastic.

Key words: *Brassica oleracea* · Growth and yield · Moisture conservation · Sawdust · White plastic

INTRODUCTION

Mulch is a material such as, decaying leaves, which can be put around a plant to protect its base and its roots, to improve the quality of the soil or stop weeds growing [1, 2]. It is a protective covering of the soil surface. It moderates summer temperatures by insulating the soil from extreme heat and cold [3]. It also prevents erosion, assists retention of soil moisture, improves soil structure, helps keep crops clean and disease free, encourages earthworm activity and acts as a weed barrier [4, 5]. When mulches are made from organic materials, they will gradually add to the soil organic matter and nutrient bank as they break down [1]. They may also encourage the growth of worms and other beneficial soil organisms that can help improve soil structure and the availability of nutrients for plants [6]. Crops that have benefited from mulching include vegetables [7].

Mulches can be differentiated into organic mulches and inorganic mulches. Organic mulches include pine bark, bark chips, compost, leaf mould, lawn clippings, pea straw, stable straw, spoiled lucerne, seaweed, mushroom compost, hay, feathers, eucalyptus mulch, manure and paper and others. Inorganic mulches include: gravel, scoria, crushed rock and synthetic plastics of various colours [1].

Mulching is very important, it can be the solution to many of the problems that beset Swazi farmers, in that it makes cultivation easier and, depending on the material used, it can also greatly enhance the visual appearance of a farm. In China plastic mulching was introduced in 1978 and has since spread fast and wide because it has made better use of limited rainfall [8, 9]. Overall mulching increases yields of crops [10, 11, 12] and improves water use efficiency [13, 14, 9].

Cabbages are a good source of Vitamin K, which is essential in the production of blood clotting proteins. Uncooked cabbage is high in glutamine, an amino acid that is essential for intestinal health [15]. Cabbage is high in potassium, which helps regulates blood pressure, promotes a steady heartbeat and can lower the risk of a stroke. 'Savoy' cabbage is among the highest in

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beta-carotene content. Cabbage contains quercetin, an antioxidant that is a natural antihistamine that can benefit allergy sufferers [16]. Cabbage juice can be used to treat stomach ulcers and help stop bleeding. Cabbage juice is used to relieve constipation. However it may cause flatulence as the juice breaks down putrefying material in the intestines. Cabbage leaves are considered ideal roughage. A chemical (isothiocyanates) found in cabbages may lower the risk of lung cancer in smokers by as much as 38% [16].

Cabbage is rich in manganese, calcium and potassium, as well as phosphorus, iron and magnesium, vitamin C, thiamin, niacin, vitamin B6 and riboflavin can be found in cabbages as well as some amounts of vitamin A, vitamin K and protein [16]. Cabbage is also a source of folate and omega-3 fatty acids, known to help with brain development in young children as well as maintain a sharp mind in adults. Cabbage has been found to have very low calorie content and is therefore perfect for weight loss. In a head of cabbage, only about 25 calories can be found. It has almost zero saturated fat content and cholesterol. It contains relatively low carbohydrates [17, 18, 16].

Eating cabbage and/or other cruciferous vegetables is associated with a decrease in the risk of many cancers including bladder, breast, lung, stomach, colorectal and prostate [19]. The anti-cancer properties of cabbage are attributed to its phytochemical content. Phytochemicals are naturally occurring and help the plant fight off disease and pests [19]. When we eat vegetables and fruits we absorb their phytochemicals (called glucosinolates in the cruciferous family), which in turn provide our bodies with defence against disease. To maximize the disease-fighting potential of these compounds the following recommendations must be adhered to: use fresh not frozen vegetables, use as little water as possible to prepare, cook for as short a time as possible and chew well [19]. Yet despite all these positive attributes little or no research has been done to ascertain mulch requirements of baby cabbage under local conditions.

Most annual vegetables crops, unlike fruit crops which are perennial, can be grown under varied climatic conditions. Vegetables such as cabbage and others can be grown in tropical, subtropical and temperate regions during the appropriate seasons [17, 7]. Acclimatised cultivars of these crops are also available to be grown successfully in climatic zones which are not otherwise suitable for certain crops. For example there are cultivars of cabbage and cauliflower particularly adapted or acclimatised to tropical regions and these varieties do extremely well in a tropical climate even though these crops are considered exotic to tropical regions [17, 18]. There is malnutrition and food scarcity in the Kingdom of Swaziland due to recurrent droughts and relatively expensive inputs for vegetable production [20] while there has been dearth of research on vegetable production using mulches in order to conserve moisture. Elsewhere under tropical conditions there has been limited research on the effect of mulches and irrigation on the production of conventional cabbage however in the dry season [6].

The study aimed at comparing bare soil (no mulch) with two different mulch materials i.e. sawdust and white plastic mulch.

MATERIALS AND METHODS

Experimental Site: The experiment was conducted from November 2008 to March 2009, in the Horticulture Department Farm, University of Swaziland, Faculty of Agriculture, Luyengo Campus. The farm is located at Luyengo, Manzini Region, in the Middleveld agro-ecological zone. Luyengo is located at 26° 34’ S and 31° 12’E. The average altitude of this area is 750 m above sea level. The mean annual precipitation is 980 mm with most of the rain falling between October and April. Drought hazard is about 40%. The average summer temperature is 27°C and winter temperature is about 15°C. The soils of Luyengo are classified under Marlkerns series. They are Ferrasolic or merely a Ferralitic soil intergrade to Fersialitic soils or typic Ultisols. The soils in the experimental area are sandy loams [21].

Experimental Layout and Design: The experimental design was a Randomized Complete Block Design (RCBD). The experiment consisted of three blocks which had three plots randomly assigned. Each plot was 3.2 m in length x 2.2 m in width and the ‘Savoy’ cabbage seedlings were planted at an inter row spacing of 40 cm and intra row plant spacing was 30 cm. The mulch treatments were white plastic sheet, saw dust (7.5 cm thick/deep) and no mulch(bare soil) acting as a control laid in the RCBD.

Materials: ‘Savoy’ baby cabbage seeds were obtained from National Agricultural Marketing Board (NAMBOARD) of Swaziland. Seeds of ‘Savoy’ baby cabbage were sown in five seedling trays. The seedling trays were filled with compost (media) obtained from Caters Garden Center, Mbabane, Swaziland. Two 10kg bags of the compost were used. The compost contained super phosphate (0%N - 10.5%P - 0%K). Watering was done using a watering can usually twice a day in the morning and late afternoon especially on hot sunny days. Fertigation was done using Nitrosol (a natural organic plant food).

Preventive fungicide and insecticide spraying was done on a weekly interval. The fungicide used was copper oxychloride and the insecticides used were Malathion 50%, Efekto Chlorpirifos and Malasol interchangeably in order to break resistance of pests to insecticide.

Soil Analysis: Soil samples were taken from the experimental area and sent to Malkerns Research Station for analysis. The experimental area soil was found to have a pH of 5.2, exchangeable acidity of 0.30 meq/100 grams, phosphorus of 40 mg/kg and potassium of 112 mg/kg. Recommendations from the research station included application of Dolomitic lime at a rate of 1 ton/ha to increase the pH. For fertiliser, the recommendation was that 2:3:4 (39) Zn applied at a rate of 555 kg/ha for medium yield or at a rate 834 kg/ha for relatively high yield of cabbage.

Land Preparation: The land was ploughed using a tractor. Marking out of plots was done using wooden pegs, a string and a measuring tape. The land was prepared to a fine tilth in readiness for transplanting. The mulching materials were installed two days before transplanting. A layer of sawdust was installed to cover each of the designated plots up to 7.5 cm thick as recommended [17]. The white plastic was of thickness of 0.008 mm, length of 30 m and width of 1.5 m obtained from South Africa. The white plastic was prepared to cover each of the designated plots.

After installing the mulches, holes were opened in both the sawdust and white plastic mulch to facilitate transplanting. In the white plastic mulch, holes of about 5 cm radius were cut out. On the seventh week after sowing the seedlings were transplanted onto the experimental area after being fertigated with Nitrosol.

Nitrosol: Nitrosol is a natural organic plant food which is manufactured by Envirogreen (PTY) Limited, Braamfontein, South Africa. It is a liquid fertiliser, readily absorbed and an environmentally safe plant nutrient recommended for the cultivation of horticultural crops especially seedlings. Nitrosol contains: 80 g/kg N, 20 g/kg P, 58 g/kg K, 7 g/kg Mg, 6 g/kg Ca, 4 g/kg S and micro elements: 60 mg/kg Fe, 1 mg/kg Cu, 1 mg/kg Zn, 40 mg/kg Mn, 23 mg/kg B and 15 mg/kg Mo. It also contains a growth stimulant of gibberelic acid at 0.003 g/kg. It is formulated from sterilised blood, bone and carcass meal.

Irrigation and Fertiliser Application: After transplanting, watering was done using sprinkler irrigation. Irrigation was done according to need i.e. phenologically, upon detecting that the soil and plant needed water. Normally it would be once in every three days after watering to field capacity. At two weeks after transplanting the first fertiliser application of 2:3:2 (22) was done at a rate of 10 grams per plant (0.8333 tonnes per ha). In the no mulch plots the fertiliser was applied using the banding method of application at about 10 cm around the plant.

The sawdust mulch was temporarily removed so that the fertiliser would be placed on the soil surface closer to plant roots. The sawdust would then cover the fertiliser to prevent volatilisation. The white plastic had to be cut in order to form a cross with the plant at the centre in order to facilitate the placement of fertiliser just below the plastic mulch at about 10 cm around the plant. The second fertiliser application was done three weeks after the first one, where limestone ammonium nitrate fertiliser (LAN) was applied at the rate of 10 grams per plant (0.8333 tonnes per ha).

Weeding: Weeding was done using a Dutch hoe, on the no mulch plots and on the foot paths between the plots. Hand weeding was done to remove weeds appearing in sawdust and white plastic mulched plots.

Data Collection: Data collection began on the second week after transplanting when the plants were fully established and continued weekly until harvest. In each plot five plants were randomly selected and tagged and monitored for data collection. The data collected included the following growth parameters: plant height, leaf area (length and width), stem diameter, head girth, fresh mass, dry mass of whole cabbage, stem length, length of roots, stem fresh mass, stem dry mass, root fresh mass, root dry mass and weed infestation.

Weed Assessment: Weed infestation was measured starting at two weeks after transplanting (WAT) and continued at two-week interval until six WAT. Dominant weed species and their distribution/composition were recorded. Weed infestation was measured just before weeding was done. Weed density was estimated visually within a 45-cm quadrat using a weed score scale from 1 to 6 (1 = no weeds on soil; 2 = sparse weed coverage; 3 = intermediate weed coverage; 4 = general weed coverage; 5 = severe weed coverage; 6 = total weed coverage) [22].Weed density was evaluated at two-week intervals using a random three point determination per plot. The weed species found in the experimental area were recorded and classified.

Data Analysis: Data collected was subjected to analysis of variance (ANOVA) using the statistical package MSTAT-C [23]. Mean separation where significant differences were detected was done using the Duncan's New Multiple Range Test [24].

RESULTS

Plant Height: There was no significant ($p>0.05$) difference in plant height at week 2, week 3, week 4 and week 7 after transplanting (ATP) between 'Savoy' baby cabbage planted with no mulch, white plastic and sawdust mulches. There was a significant ($p<0.05$) difference in plant height at week 5 and week 6 ATP (Fig. 1). Baby cabbage plants grown in sawdust mulch were found to have a higher plant height followed by plants in white plastic mulch and lastly the plants in the control (bare soil). At 5 WAT the mean plant height for no mulch, white plastic and sawdust was 18.9 cm, 24.5 cm and 25.5 cm respectively. At 6 WAT the mean plant height was 20.9 cm, 26.4 cm and 31.1 cm for no mulch, white plastic and sawdust respectively. At 7 WAT the mean plant height for no mulch, white plastic and sawdust treatments was 23.2 cm, 26 cm and 27.3 cm respectively (Fig.1).

Stem Diameter: There was no significant ($p>0.05$) difference in stem diameter between 'Savoy' baby cabbage grown with no mulch, white plastic mulch and sawdust mulch at two weeks ATP. There was a significant ($p<0.05$) difference in stem diameter between the three treatments, at four, five, six and seven weeks after transplanting (Fig. 2). Stem diameter was found to be relatively higher for plants from both white plastic and sawdust mulched soil than plants from bare soil.

Leaf Area: There was no significant ($p>0.05$) difference in leaf area at 2 and 3 weeks ATP for the three treatments. There was a significant ($p<0.05$) difference in leaf area at four, five, six and seven weeks ATP (Fig. 3). Although statistically the leaf area of plants from sawdust mulched plants was not significantly different to leaf area of plants from white plastic; however, sawdust had a higher mean leaf area than white plastic in terms of trend. The significant ($p<0.05$) difference was realised when white plastic and sawdust are compared to the control. Leaf area was relatively higher in plants mulched with white plastic and sawdust. At 4 WAT the mean leaf area was 139.1 cm^2, 301.7 cm^2 and 269.3 cm^2 for plants from no mulch, white plastic and sawdust treatments respectively. The mean leaf area at 5 WAT was 178.9 cm^2 for no mulch, 334.9 cm^2 for white plastic and 341.3 cm^2 for sawdust treatments. At six WAT the mean leaf area of plants from no mulch, white plastic and sawdust treatments was 206.7 cm^2, 392.1 cm^2 and 420.3 cm^2 respectively. At 7 WAT the mean leaf area of plants was 206.1 cm^2, 393.1 cm^2 and 430.9 cm^2 for no mulch, white plastic and sawdust treatments respectively (Fig. 3).

Weed Infestation: There was a significant ($p<0.05$) difference in plot weed infestation between no mulch, white plastic mulch and sawdust mulch at all the weeks when weed infestation was recorded (Fig. 4). The no mulch plot had relatively the highest weed infestation compared to the other treatments. Sawdust allowed weeds to germinate and grow through the mulch at a relatively higher rate than in white plastic mulch sometimes even similar to no mulch. The mean weed score at 2 WAT was 4.0 for no mulch, 2.0 for white plastic and 3.2 for sawdust. At 4 WAT the mean weed score was 4.6, 2.0 and 4.0 for no mulch, white plastic and sawdust respectively. At 6 WAT the mean weed score for no mulch, white plastic and sawdust was 4.8, 2.0 and 4.0 respectively. The various weeds found in the plots used for growing 'Savoy' baby cabbage are shown in Table 1.

Yield: There was a significant ($p<0.05$) difference in fresh mass yield of 'Savoy' baby cabbage between the three treatments (Fig. 5). There was a significant ($p<0.05$) difference in dry mass yield of 'Savoy' baby cabbage. There was no significant ($p>0.05$) difference in stem length, fresh and dry mass of stem, length of roots and fresh and dry mass of roots between the three treatments. Although, the difference between plastic mulch and sawdust was not significant statistically, the mean yield in white plastic mulch was relatively higher than the mean yield in sawdust mulch. The control produced relatively the lowest yield of 'Savoy' baby cabbage. The yield of 'Savoy' baby cabbage expressed in fresh mass was 22.06 tons/ha for no mulch, 38.69 tons/ha for sawdust and 41.15 tons/ha for white plastic mulched plants. The yield expressed in dry mass was 2.65 tones/ha for no mulch, 4.53 tons/ha for sawdust and 4.71 tons/ha for white plastic mulched plants (Fig. 5).

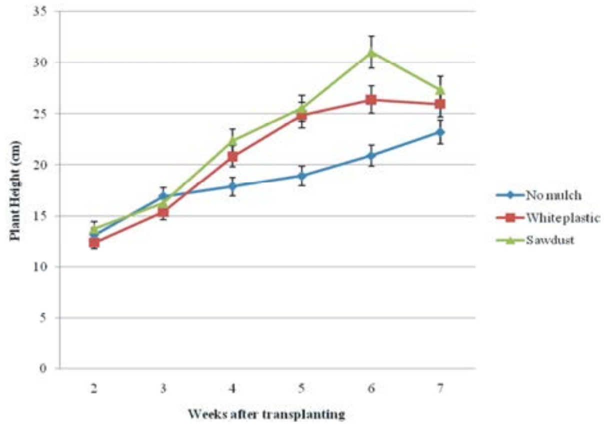

Fig. 1: Plant height of 'Savoy' baby cabbage mulched with white plastic or sawdust. A vertical bar is the standard error to compare treatments within an interval

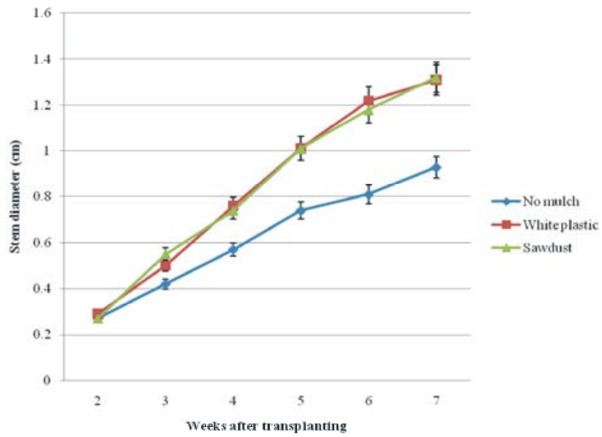

Fig. 2: Stem diameter of 'Savoy' baby cabbage mulched with white plastic or sawdust. A vertical bar is the standard error to compare treatments within an interval

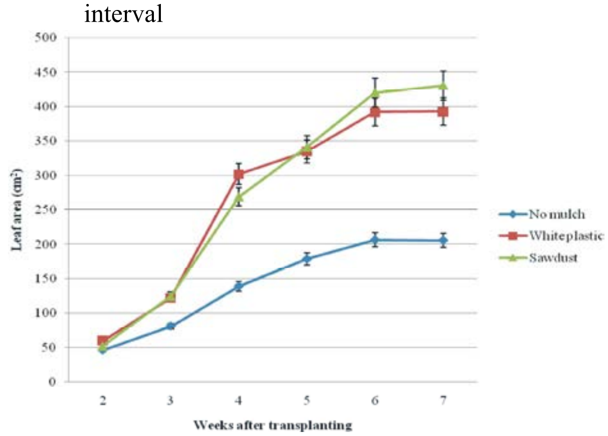

Fig. 3: Leaf area of 'Savoy' baby cabbage mulched with white plastic or sawdust. A vertical bar is the standard error to compare treatments within an interval

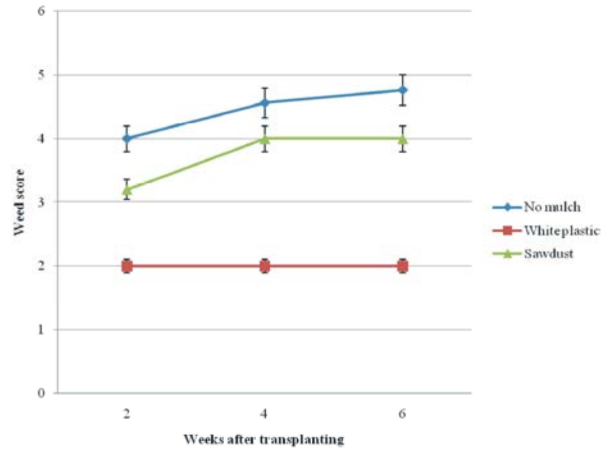

Fig. 4: Weed infestation of 'Savoy' baby cabbage plot mulched with white plastic or sawdust. A vertical bar is the standard error to compare treatments within an interval

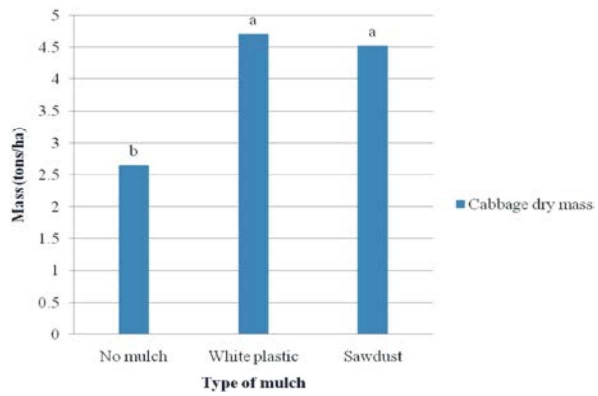

Fig. 5: Yield of 'Savoy' baby cabbage mulched with white plastic or sawdust, Treatments with the same letter indicate no statistical differences

Table 1: Classification of weeds found in the experimental plot

Common name	Scientific name	Family
Apple of Peru	*Nicandra physalodes* L.	Solanaceae
Bengal wondering Jew	*Commelina benghalensis* L.	Commelinaceae
Crab finger grass	*Digitaria sanguinalis* L.	Poaceae
Dwarf marigold	*Schkuhria bonariensis,* L	Compositae
Painted milkweed	*Euphorbia heterophylla* L.	Euphorbiaceae
Red garden sorrel	*Oxalis latifolia*	Oxalidaceae
Thorn apple	*Datura stramonium* L.	Solanaceae
Tropical richardia	*Richardia brasilensis*	Rubiaceae
Yellow nutsedge	*Cyperus esculentus* L.	Cyperaceae

Head Girth: There was significant ($p < 0.05$) difference in cabbage head girth from the various treatments. The mean head girth was 15.6 cm for no mulch, 28.7 cm for white plastic and 24.3 cm for sawdust. The mean stem length was 11.6 cm for no mulch, 11.4 cm for white plastic and 12.1 cm for sawdust (Fig. 6).

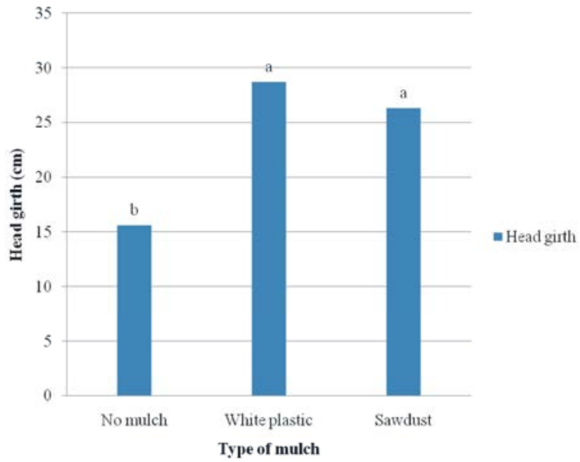

Fig. 6: Head girth of 'Savoy' baby cabbage mulched with white plastic or sawdust. Treatments with the same letter indicate no statistical differences

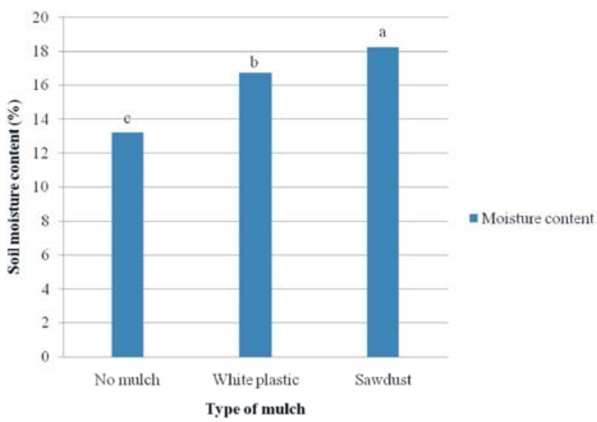

Fig. 7: Percentage soil moisture retained as influenced by white plastic and sawdust mulches. Treatments with the same letter indicate no statistical differences

Moisture Retention: There was a significant ($p<0.05$) difference in soil moisture retention among the three treatments (Fig. 7). No mulch was poor in retaining moisture within three days irrigation interval. The mean soil moisture retained was 13.2 % in no mulch, 16.7% in soil covered with white plastic and 18.3 % in in soil covered with sawdust mulch (Fig. 7).

DISCUSSION

There was a significant ($p<0.05$) difference in plant height at week 5 and week 6 ATP. Baby cabbage plants grown in sawdust mulch were found to have a higher plant height followed by plants in white plastic mulch and lastly the plants in the control. The findings of this study were consistent with findings by Matsenjwa [25] who reported that both plastic and organic mulch increased plant height of field bean under similar conditions. Baby cabbage plants grown in white plastic mulch initially had their stems bent due to complications and difficulties faced when transplanting. The plants had to be transplanted to the ground through holes of about 5 cm radius made on the white plastic. At week 7 ATP there was no significant ($p>0.05$) difference in plant height because the 'Savoy' baby cabbages had already began folding their leaves for the formation of the cabbage head/heart. Previously and elsewhere mulching has been reported to increase growth of crops [10, 11, 12].

There was no significant ($p>0.05$) difference in stem diameter between 'Savoy' baby cabbage grown with no mulch, white plastic mulch and sawdust mulch at two weeks ATP. There was a significant ($p<0.05$) difference in stem diameter between the three treatments, at 4, 5, 6 and 7 weeks after transplanting. Stem diameter was found to be relatively higher for plants from both white plastic and sawdust mulches. The findings are in agreement with those of [10, 11], that plastic mulches and organic mulches increased plant growth which included stem diameter and improves water use efficiency [13, 14].

There was no significant ($p>0.05$) difference in leaf area at two and three weeks ATP. There was a significant ($p<0.05$) difference in leaf area at 4, 5, 6 and 7 weeks ATP. Although statistically the leaf area of plants from sawdust was not significantly ($p>0.05$) different to leaf area of plants from white plastic; however, sawdust had a higher mean leaf area than white plastic in terms of trend. The significant ($p<0.05$) difference was realised when white plastic and sawdust are compared to the control. Leaf area was relatively higher in plants mulched with white plastic and sawdust. The findings were consistent with those of Carmichael *et al*. [26] who reported that plastic mulch and organic mulch increased leaf area in radish.

There was a significant ($p<0.05$) difference in plot weed infestation between no mulch, white plastic mulch and sawdust mulch in all the weeks when weed infestation was assessed and recorded. The no mulch plot had relatively the highest weed infestation compared to the other treatments. Sawdust allowed weeds to germinate and grow through the mulch at a relatively higher rate than white plastic mulch sometimes even similar to no mulch. The 7.5 cm deep sawdust mulch was less effective in suppressing weeds than white plastic. White plastic mulch had the lowest weed infestation and was seen to be effective in weed suppression because weeds could only be seen just around the plastic mulch openings for the cabbage plants. Similar findings of plastic mulch supressing weed growth have been reported [12, 5, 9].

There was a significant ($p<0.05$) difference in fresh mass yield and head girth of 'Savoy' baby cabbage between the three treatments, where mulched plants had higher yield than plants from bare soil [6, 10, 11, 12]. The mulches used in this experiment may have lowered temperature making it favourable for plant growth [17, 18] since cabbage is a cool season vegetable. Mulches can have a temperature change effect of 0.5-3°C [6,9] depending on conditions. There was a significant ($p<0.05$) difference in dry mass yield of 'Savoy' baby cabbage. There was no significant ($p>0.05$) difference in stem length, fresh and dry mass of stem, length of roots and fresh and dry mass of roots between the three treatments. Although, the difference between plastic mulch and sawdust was not significant statistically, the mean yield in white plastic mulch was relatively higher than the mean yield in sawdust mulch. The control realised relatively the lowest yield of 'Savoy' baby cabbage. Mulching, through its marked effects on the soil environment offers great potential of increasing crop growth and yield [6, 9, 14, 27]. The findings differed with Matsenjwa [25], who reported that plastic mulches and organic mulches did not increase yield of field bean but increased vegetative growth.

There was a significant ($p<0.05$) difference in moisture retention of soil previously covered with white plastic mulch or sawdust mulch. Bare soil (no mulch) was poor in retaining moisture within three days irrigation interval. Soils mulched with plastic mulches lose less moisture from evaporation [5, 9, 12, 26] and improves soil microbial biomass [28]. Plastic mulch protects soil from leaching, rain; hence the soil needs less fertilizer [27]. White plastic retained 3.5% more moisture than the control; whereas sawdust mulch retained 1.5% more soil moisture than white plastic mulch.

The reason for soil moisture retained by white plastic mulch to be lower than soil moisture retained by sawdust mulch may be because white plastic mulch allowed less amounts of water into the soil while sawdust allowed more water thus being able to retain more water in the soil. This was because of the sprinkler irrigation system which was used to irrigate the 'Savoy' baby cabbage plots. The recommended irrigation system used with plastic mulches is drip irrigation system. The easiest way to irrigate with plastic mulch is to install a drip irrigation system, or lay soaker hoses on the surface of the rows before covering them with plastic [27].

It may be interesting to do benefit/cost analysis of using various mulches available in local communities not only in cabbage production but other vegetables. The idea being to come up with relatively cheaper materials to use in vegetable production while obtaining maximum benefits possible with least negative externalities to the environment bearing in mind impending climate change and the need for sustainability.

CONCLUSION AND RECOMMENDATION

This investigation showed that white plastic mulch and sawdust improved yields of baby cabbage, conserved moisture and that white plastic mulch suppressed weeds. It may be more informative to record temperatures in the soil during crop growth. It may be recommended that farmers use plastic and sawdust mulches in baby cabbage production. It may be helpful to conduct further research using locally available mulch materials in local communities.

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