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Effects of Mulching Materials on the Growth and Yield of Peanuts Cultivated in Coastal Areas of Thanh Hoa Province

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Abstract

Mulches have been widely applied in crop production in order to minimize water requirements, preserve soil moisture, and curb weed growth for higher yield and water use efficiency. This research aimed to assess the impact of organic mulches on peanut productivity in the coastal areas of Thanh Hoa province. The experiment was carried out during the 2019 spring growing season. A split pot design was used with two peanut cultivars (L14 & L23) as the main plots and five types of mulching materials (clear plastic, rice straw, sugarcane bagasse, water hyacinth, and bare soil) as the subplots. It was revealed that rice straw exhibited a positive influence on the growth attributes and yield of peanuts, comparable to clear plastic and other organic mulch materials. Notably, rice straw contributed to enhanced plant growth, dry matter production, pod filling, and yield. Additionally, the net return of rice straw application was also the highest. The results suggested that organic mulching materials (rice straw and plant residues) can be effectively used for peanuts because of their availability and biodegradability as an eco-friendly agricultural practice.

Keywords

Mulching materials, net return, peanut, yield

Introduction

Topsoil mulching is a widely recognized practice in crop farming that helps control the microclimate around plants due to its positive effects in controlling weeds and temperature and conserving soil water/moisture; all these benefit crop yields (Pedda Ghouse Peera, 2020; Sharma & Menon, 2020; Basit *et al.*, 2022)**.** Mulch is defined as any material that is spread or laid over the surface of the soil and used as a covering for different roles and purposes. Mulches have widely been used in crop and vegetable production since ancient civilizations (Lightfoot, 1994), including the Egyptians, who used

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straw and other organic materials to cover the soil in their fields and gardens, and ancient Greeks and Romans, to enrich the soil and suppress weeds. Today, the benefits of mulches in agriculture, particularly in horticulture, are widely known and recognized. Functionally, mulches as materials applied in crop production reduce soil evaporation, conserve soil moisture, suppress weed growth and insect infestations, control soil structure and temperature, influence soil micro-organisms, and improve crop yield (Iqbal *et al.*, 2020; Sagar *et al.*, 2020; Amare & Desta, 2021), and, thus, save water for dryland agriculture (Kader *et al.*, 2019) and enhance seedling establishment in arid and semiarid climatic conditions (Choudhary *et al.*, 2022).

However, the effects of mulching on the soil environment depend on soil properties, climate, crop, and type of mulch. Mulching materials include plastics, organic materials (crop residue, stubble mulch), and other natural products. Different from plastic mulch, organic mulch adds nutrients to the soil when composted.

Peanuts, a short-growth duration crop of economic value, are widely grown on sandy soil in Quang Xuong district, Thanh Hoa province. Peanut crops require sufficient soil moisture for growth and yield formation. Islam *et al.* (2021) reported that mulching positively increased yield, i.e., higher fruit yield per plant and fruit yield per hectare, than the un-mulched controls for tomato, eggplant, paprika, and broccoli. Organic mulches (newspaper, bran, and grass) were reported to improve water use efficiency and the yield of tomatoes in the greenhouse (Zhang *et al.*, 2023).

Several studies on mulching for peanuts have been carried out using polyethylene (plastics). It was shown that plastic mulch improved the growth and yield of peanuts (Vu Ngoc Thang & Vu Dinh Chinh, 2007; Nguyen Thi Chinh, 2009). Ramakrishnan *et al.* (2006) reported that plastic and rice straw mulch positively affected the growth and development of peanuts on red-yellow ferrallitic soil in the highland region in northern Vietnam. On the coastal sandy soil conditions in Nghe An province, most of the plant growth parameters, yield components, and yield of peanuts under mulching were significantly higher than those of the no-mulch control. Among the mulches, plastic mulch was superior to straw mulch in pod yield, water use efficiency, and moisture conservation (Tran *et al.*, 2022). Plastic mulches directly impact the microclimate around the plant by modifying the radiation budget (absorptivity vs. reflectivity) of the surface and decreasing soil water loss. Black plastic was found to be ideal for eliminating weeds, reducing pest populations, warming up the soil during the cold season, retaining the soil's moisture, and even increasing yield by 20% compared to clear plastic mulching (Zhu *et al.*, 2022), while clear plastic worked best for warming up the soil and encouraging faster growth early in the growing season. However, plastic mulching causes adverse effects on the field environment, making it difficult for the next crop planting. Due to its short life, plastic debris from mulching results in both soil contamination and environmental pollution (Khalid *et al.*, 2023). Organic materials, such as rice straw, sugarcane bagasse, water hyacinth, grass, and others are readily available in rural areas and can be used as crop mulch. In Vietnam, rice production produces more than 40 million tons of rice straw per annum. The use of organic materials as mulching for peanuts have similar benefits to plastics, as they not only retain soil moisture but also control weeds, improve the physical properties of the soil, and reduce soil erosion (Ha Dinh Tuan *et al.*, 2005; Vu Ngoc Thang & Vu Dinh Chinh, 2007; Vu Van Liet *et al.*, 2010; Le Quoc Thanh *et al.*, 2014). However, studies on the use of organic mulching for rainfed peanut cultivation on sand or sandy loam soil in coastal areas are rare. In these areas, spring peanut (from early February to May) is the main crop. The most critical constraints in this cropping season are lower temperatures and humidity, which affect seed germination and crop establishment. The use of available organic materials might reduce production costs and, more importantly, regulate temperature and soil moisture, minimize the adverse impacts on agroecology, and improve soil health in both the short and long term.

The objective of this study was to compare the performance of organic mulching materials with clear plastic mulch, which is widely used due to its availability and convenience, in terms of growth and yield of peanuts on sandy loam soil in the coastal area in Thanh Hoa province.

Materials and Methods

The mulching experiments were conducted on two peanut varieties, L14 and L23, on land specialized for non-rice crops in Hop Luc village, Quang Hop commune, Quang Xuong district, Thanh Hoa province between early February and May 2019. L14 is high-yielding and is currently a common peanut cultivar in Thanh Hoa. L23 is drought tolerant. Both cultivars are also appropriate for Thanh Hoa province based on the field testing results for the release of these cultivars. The texture of the topsoil (0-30cm) was sandy loam with a bulk density of 1.58 g cm^{-3}. The mulching materials were clear plastic film (polyethylene), rice straw, sugarcane bagasse, and water hyacinth. Non-mulched (bare) soil was the control. The treatments were arranged in a split-plot design with three replications, with the cultivars as the main plot and the mulching materials as the subplot. The plot size was $10m^2$ and the planting density was 40 plants m^{-2}. Each plot was planted with four rows along the plot length.

The experiment received a total fertilizer application (treatments and control) of 10tons of farm yard manure + 30kg N + 80kg P_2O_5 + 60kg K_2O + 500kg lime powder for 1ha. For the mulching treatments, the total amount of fertilizer and lime was applied once before sowing, while the control fertilizer was split into two applications. Cultivation practices, including irrigation, were applied as conventionally practiced in the area.

The organic mulches (rice straw, bagasse, and water hyacinth) were chopped into 6-7cm pieces and applied evenly to cover the soil surface immediately after sowing. The organic materials covered the soil with a thickness of 4cm (approximately 5 tons of dry matter per hectare). The clear plastic was spread over the plots after sowing and holes were made upon emergence.

The data recorded consisted of the percentage of emergence, branching and plant height, leaf area index, dry matter accumulation, and nodulation at different growth stages (*i.e.*, flowering, podding, and full seed stages), abundance level of the weed population, yield components, and yield.

Leaves on a land unit were collected for the estimation of leaf area index (LAI). Each sampled leaflet was cut into leaf segments square in size. The total leaves and the leaf segments were weighed using an electronic weighing machine. The following equation was employed to measure the leaf area index:

$$\text{LAI} = \frac{X}{Y} \text{ x } W$$

where X and Y represent the leaf segment area (cm^2) and its weight (g), respectively, while W represents the weight (g) of the leaves harvested on a land unit.

The plant dry weight was determined by oven drying until a constant final weight was reached.

The number of nodules was counted at the flowering, podding, and full seed stages on ten plants in the middle rows of each plot. Effective nodules were determined by cutting the nodules open and observing the internal color. Nodules that were deep red in color were active, indicating that conditions were optimal for *Rhizobia* to perform their nitrogen-fixing function. Ineffective nodules had a small size with a lighter, whitish, or greenish internal color.

At harvest, ten plants per plot were determined for the number of pods/plant, 100 pod weight (at 10% moisture), 1000 seed weight, shelling percentage, and pod yield. The degree of weeds was determined at peak flowering.

The net profit was calculated based on total revenue and total cost as follows:

Net profit (VND/ha) = Total revenue – Total cost

The data were statistically analyzed using Microsoft Excel 10 and IRRISTAT version 5.0 for analysis of variance (two-way ANOVA). The least significant difference ($P \leq 0.05$) calculated by IRRISTAT was used for pairwise mean comparisons.

Results

Effect of mulching materials on the emergence of peanuts

Mulching by either plastic or organic materials increased the seedling emergence rate and shortened the time from sowing to emergence (**Table 1**). This can be explained in that mulching retained soil moisture and maintained higher soil temperatures during the cooler days in early February.

Effects of mulching materials on the branching and plant height of peanuts

Mulching materials exerted positive and significant effects on branching and plant height in peanuts. The peanut plants reached their final heights at the full seed stage. The number of branches per plant and plant height was higher for all the types of mulch, in the range of 4.70-5.90 for primary branches and 42.7-48.3cm for plant height at the full seed stage (**Table 2**). Polyethylene and rice straw were superior to sugarcane bagasse and water hyacinth. The number of primary branches for L14 was significantly different among the mulching types (LSD = 0.18) while the values for L23 under clear plastic and rice straw were significantly higher than non-mulching. Although the plant heights of L14 were not significantly different among the mulching types, the plant heights of L23 under clear plastic (48.3cm) and rice straw (48.0cm) were significantly higher than those with non-mulching (46.0cm).

Effects of mulching materials on the leaf area (LAI) and dry matter accumulation of peanuts

LAI attained the highest values at the podding stage and declined remarkably until the full seed period. The values for LAI obtained in this study (**Table 3**) were similar to those reported in the literature on peanuts (Nguyen *et al.*, 2016; Tran *et al.*, 2022). At all growth stages, LAI under mulching was significantly higher than the non-mulching treatment ($P < 0.05$), and cv. L23 showed a higher value as compared to cv. L14. The organic mulches improved leaf area in both cultivars compared to the control and were comparable to using clear plastic, with rice straw as mulch showing an acceptable effect. For example, across both cultivars, the LAI mean at podding for the control (non-mulching) was 5.21, while those for the organic materials were significantly higher in the range of 5.44-5.67 and for clear plastic was 5.79 (LSD = 0.18 for mulching type).

Mulches significantly improved dry matter production in all growth stages compared to the bare soil control. The highest dry matter was recorded for clear plastic (45.91 g/plant), followed by rice straw (44.61 g/plant), while lesser values were found for sugar cane bagasse (43.99 g/plant) and water hyacinth (43.83 g/plant). This is in line with several studies that found the growth characteristics of peanuts were highest under polythene mulching, followed by rice straw mulching (Dutta, 2006; Jain *et al.*, 2018; Tran *et al.*, 2022).

Table 1. Effect of mulching materials on the time from sowing to emergence and seedling emergence rate of peanuts

Mulching material	Peanut cultivar	Days to seedling emergence (days)	Emergence rate (%)
Non-mulching	L14	16	88.9
	L23	15	90.9
Clear plastic	L14	11	97.3
	L23	11	98.4
Rice straw	L14	12	96.7
	L23	11	98.2
Sugarcane bagasse	L14	12	96.3
	L23	12	97.9
Water hyacinth	L14	13	95.5
	L23	12	97.3

Table 2. Effect of mulching materials on the branching and plant height of two peanut cultivars at the flowering and full seed stages

Mulching material	Peanut cultivar	Flowering stage: Number of primary branches (branches/ plant)	Flowering stage: Number of secondary branches (branches/ plant)	Full seed stage: Number of primary branches (branches/ plant)	Full seed stage: Number of secondary branches (branches/ plant)	Plant height at full seed stage (cm)
Non-mulching	L14	4.43^{e}	1.27^{f}	4.43^{e}	2.26^{e}	42.3^{d}
	L23	5.37^{b}	1.86^{d}	5.37^{b}	2.67^{c}	46.0^{c}
Clear plastic	L14	4.93^{c}	1.73^{de}	4.93^{c}	2.67^{c}	43.7^{d}
	L23	5.90^{a}	2.53^{a}	5.90^{a}	3.67^{a}	48.3^{a}
Rice straw	L14	4.83^{cd}	1.66^{e}	4.83^{cd}	2.53^{cd}	43.3^{d}
	L23	5.77^{a}	2.36^{b}	5.77^{s}	3.56^{a}	48.0^{ab}
Sugarcane bagasse	L14	4.76^{cd}	1.40^{f}	4.76^{cd}	2.43^{d}	43.0^{d}
	L23	5.56^{b}	2.23^{bc}	5.56^{b}	3.36^{a}	47.0^{ab}
Water hyacinth	L14	4.70^{d}	1.36^{f}	4.70^{d}	2.36^{de}	42.7^{d}
	L23	5.47^{b}	2.16^{c}	5.47^{b}	3.13^{b}	46.6^{bc}
CV%		2.10	4.30	2.10	2.90	3.2
$LSD_{0.05\ Mulch}$		*0.18*	*0.19*	*0.18*	*0.13*	*1.6*
$LSD_{0.05\ Cultivar}$		*0.86*	*0.65*	*0.86*	*0.68*	*2.6*
$LSD_{0.05\ Mulch \times Cultivar}$		*0.19*	*0.14*	*0.19*	*0.15*	*1.53*

Note: CV =coefficient of variation; LSD = Least significant difference at P ≤0.05. Different superscript letters show interaction significance among mulching materials and peanut cultivars at P ≤0.05.

Effects of mulching materials on the nodulation of peanuts

The mulching materials showed a significant influence on nodulation. The recorded numbers of effective nodules/plant were higher in all the mulch types as compared with bare soil throughout the growth stages (**Table 4**). For example, effective nodules at the flowering stage for bare soil were 39.47-52.90 (for both cultivars), while those for the other mulching materials were higher and in the range of 44.00-58.87. Nodulation also reached the highest at the podding stage and reduced at the full seed stage for both cultivars.

Effect of mulching materials on the weed population of peanuts

The weed composition and level were affected by the mulch materials. While weeds were abundant on bare soil, the plastic mulch and organic mulching materials completely suppressed certain weed species (**Table 5**). The lowest weed populations were recorded in plastic and rice straw mulch, with 1-2 main weed species present, thus reducing competition and minimizing weeding costs. Ramakrishnan *et al.* (2006) reported that polyethylene and rice straw mulch promoted growth and effectively suppressed weed infestations. Thus, using rice straw as mulch provides an attractive and environment-friendly option since rice straw is plentiful in Vietnam.

Effect of mulching materials on the yield components and yield of peanuts

Mulching improved the peanut yield components, particularly pod number per plant, seed size/weight, and shelling percentage (**Table 6**). The mean number of pods per plant across both cultivars was minimum in the non-mulching treatment (8.7 pods) and highest in clear plastic (10.2 pods), followed by rice straw (10.1 pods), sugarcane bagasse (9.9 pods), and water hyacinth (9.7 pods). Rice straw seemed superior and comparable to clear plastic and organic mulches for all the yield-related traits. Plastic mulch and

Table 3. Effect of mulching materials on the leaf area index (LAI) and dry matter accumulation (g/plant) of two peanut cultivars at the flowering, podding, and full seed growth stages

Mulching material	Peanut cultivar	LAI (m^2 leaf/m^2 land)				Dry matter accumulation (g/plant)			
		Flowering stage	Podding stage	Full seed stage	Cross cultivar LAI means at podding stage	Flowering stage	Podding stage	Full seed stage	Cross cultivar dry matter means at full seed stage
Non-mulching	L14	2.28^{h}	4.94^{f}	3.28^{f}	5.21	4.18^{c}	7.79^{c}	38.64^{c}	43.54
	L23	3.35^{d}	5.47^{c}	3.88^{cd}		5.87^{b}	9.99^{b}	48.44^{a}	
Clear plastic	L14	3.23^{d}	5.65^{bc}	3.97^{c}	5.79	4.54^{c}	8.29^{c}	41.64^{b}	45.91
	L23	3.97^{a}	5.93^{a}	4.48^{a}		6.41^{a}	10.55^{a}	50.18^{a}	
Rice straw	L14	3.01^{e}	5.45^{cd}	3.67^{de}	5.67	4.49^{c}	8.16^{c}	39.27^{b}	44.61
	L23	3.73^{b}	5.86^{ab}	4.32^{ab}		6.32^{a}	10.41^{ab}	49.95^{a}	
Sugarcane bagasse	L14	2.79^{f}	5.29^{de}	3.54^{e}	5.49	4.47^{c}	8.08^{c}	39.09^{bc}	43.99
	L23	3.61^{bc}	5.68^{b}	4.24^{b}		6.20^{ab}	10.27^{ab}	48.89^{a}	
Water hyacinth	L14	2.62^{g}	5.20^{e}	3.51^{e}	5.44	4.41^{c}	7.99^{c}	38.85^{bc}	43.83
	L23	3.55^{c}	5.67^{b}	4.14^{bc}		6.15^{ab}	10.25^{ab}	48.80^{a}	
CV%		2.14	2.20	2.90		3.90	3.10	3.50	
$LSD_{0.05\ Mulch}$		0.11	0.18	0.16		0.30	0.41	2.61	
$LSD_{0.05\ Cultivar}$		0.68	0.99	0.93		0.16	0.23	1.27	
$LSD_{0.05\ Mulch \times Cultivar}$		0.15	0.22	0.21		0.37	0.51	2.85	

Note: CV =coefficient of variation; LSD = Least significant difference at P ≤0.05. Different superscript letters show interaction significance among mulching materials and peanut cultivars at P ≤0.05.

Table 4. Effect of mulching materials on the nodulation of two peanut cultivars at the flowering, podding, and full seed stages

Mulching material	Peanut cultivar	Effective nodules at flowering stage (no. nodules/plant)	Effective nodules at podding stage (no. nodules/plant)	Effective nodules at full seed stage (no. nodules/plant)
Nonmulching	L14	39.47^{d}	95.83^{c}	81.17^{b}
	L23	52.90^{b}	121.93^{a}	103.73^{a}
Clear plastic	L14	47.0^{bc}	104.90^{b}	90.30^{b}
	L23	58.87^{a}	129.13^{a}	113.93^{a}
Rice straw	L14	46.27^{c}	103.47^{bc}	88.53^{b}
	L23	57.83^{ab}	128.20^{a}	112.97^{a}
Sugarcane bagasse	L14	45.50^{c}	100.20^{bc}	86.33^{b}
	L23	56.57^{ab}	126.83^{a}	109.27^{a}
Water hyacinth	L14	44.0^{cd}	98.86^{bc}	83.23^{b}
	L23	55.47^{ab}	124.87^{a}	108.03^{a}
$CV_{\%}$		6.50	4.10	6.00
$LSD_{0.05\ Mulch}$		3.99	8.44	7.86
$LSD_{0.05\ Cultivar}$		2.66	3.80	4.77
$LSD_{0.05\ Mulch \times Cultivar}$		5.97	8.50	10.68

Note: CV =coefficient of variation; LSD = Least significant difference at P ≤0.05. Different superscript letters show interaction significance among mulching materials and peanut cultivars at P ≤0.05.

Table 5. Effect of mulching materials on the abundance level of the weed population of two peanut cultivars

Mulching material	Peanut cultivar	Weed species				
		Goat weed	Swamp fox glove	Chinese sprangletop	Goose grass	Others
Non-mulching	L14	++	++	+++	+++	++
	L23	++	++	+++	+++	++
Clear plastic	L14	-	-	-	+	-
	L23	-	-	-	+	-
Rice straw	L14	+	-	+	-	+
	L23	+	-	+	-	+
Sugarcane bagasse	L14	+	+	+	+	+
	L23	+	+	+	+	+
Water hyacinth	L14	+	+	+	+	+
	L23	+	+	+	+	+

Note: +++: Abundant; ++: moderate; +: low; -: extremely low.

Table 6. Effect of mulching materials on the yield components and yield of two peanut cultivars

Mulching material	Peanut cultivar	Pod number per plant	Cross cultivar means of pod number per plant	100-pod weight (g)	100-seed weight (g)	Cross cultivar means of 100-seed weight (g)	Shelling percentage (%)	Pod yield (kg/ha)	Cross cultivar means of pod yield (kg/ha)
Non-mulching	L14	8.2^{e}	8.7	135.7^{b}	54.3^{b}	141.2	71.54^{b}	3180^{e}	3482
	L23	9.2^{d}		146.7^{a}	56.7^{ab}		71.87^{ab}	3784^{c}	
Clear plastic	L14	9.7^{c}	10.2	136.7^{b}	55.0^{ab}	142.0	73.23^{a}	3767^{c}	4109
	L23	10.7^{a}		147.3^{a}	57.3^{a}		73.56^{a}	4452^{a}	
Rice straw	L14	9.5^{cd}	10.1	136.3^{b}	54.7^{b}	141.8	72.87^{ab}	3684^{cd}	4026
	L23	10.6^{ab}		147.3^{a}	57.3^{a}		73.16^{a}	4368^{a}	
Sugarcane bagasse	L14	9.4^{cd}	9.9	136.3^{b}	54.7^{b}	141.7	72.65^{ab}	3598^{cd}	3958
	L23	10.3^{b}		147.0^{a}	57.0^{ab}		73.08^{a}	4319^{ab}	
Water hyacinth	L14	9.2^{d}	9.7	136.0^{b}	54.3^{b}	141.3	72.26^{ab}	3512^{d}	3837
	L23	10.1^{b}		146.7^{a}	56.7^{ab}		72.73^{ab}	4162^{b}	
$CV_{\%}$		2.20		3.60	2.40		2.35	3.00	
$LSD_{0.05\ Mulch}$		0.24		7.68	1.79		1.23	195	
$LSD_{0.05\ Cultivar}$		0.17		4.16	1.08		1.19	94	
$LSD_{0.05\ Mulch \times Cultivar}$		0.39		9.31	2.42		1.43	210	

Note: CV =coefficient of variation; LSD = Least significant difference at P ≤0.05. Different superscript letters show interaction significance among mulching materials and peanut cultivars at P ≤0.05.

rice straw better retained soil moisture and suppressed weeds for higher assimilation of photosynthates and better partitioning of assimilates resulting in increased reproductive structures as visible by the yield components.

The 100-pod and 100-seed weights for the two cultivars under mulching varied from 136.0-147.4g and 54.3-57.3g, respectively, and were higher than the control (135.7-146.7g and 54.3-56.7g). However, the differences between the mulching types and the control were not statistically significant. This observation is also similar to the results of Tran *et al.* (2022).

Similarly, the shelling percentage was higher in the mulching treatments (in the range of 72.26-73.23%) compared to non-mulching (71.54-71.87%). Significant differences compared to the control in the shelling percentage were observed in clear plastic and rice straw for L14 and L23 (LSD = 1.23% for mulching type). This indicates that pod filling under the mulching conditions was more efficient. This agrees with the results of Jain *et al.* (2017) who reported more reproductive peanut pods and better seed filling under the unstressed environment of mulching.

The mulch treatments consistently resulted in significantly higher yields than the bare soil control (**Table 6**). Among the mulches, plastic mulch had a greater yield (4109 kg/ha) than rice straw (4026 kg/ha), but there was no significant difference. The favorable micro-climate under mulching increased pod yields by 11.8% and 11.6% under plastic and rice straw mulch, respectively, over no mulch. Similar increases in peanut yield due to mulching have been reported in previous studies (Ramakrishnan *et al.*, 2006; Jain *et al.*, 2017). Tran *et al.* (2022) reported a slightly higher yield increase for L14 (16% for plastic mulch and 12.8% for straw mulch) than this study.

Economic efficiency of mulching practices on peanuts

The application of mulching materials for both peanut cultivars brought higher total revenues and net profits (**Table 7**). The relative net return increase obtained from mulching treatments over the bare soil control ranged from 12.5-14.4%. Notably, the net return from rice straw mulch was highest (~27.1-35.9 million VND), followed by sugarcane bagasse (~25.6-35.0 million VND), due to the lower cost of these mulching materials compared with polyethylene (net return of about 24.8-33.8 million VND). The use of rice straw or sugarcane as organic mulch to the soil not only improved the growth and yield of the crop but more importantly returned a significant amount of organic matter to the soil for the next cropping season.

Discussion

There are two categories of mulch: inorganic and organic. Inorganic mulch is of a synthetic nature and not made of natural materials. The most common inorganic mulch is polyethylene (transparent, black, or other colors). Inorganic mulches are good for holding moisture and blocking weeds, but they do not add any nutrients to the soil and potentially contaminate cultivated soil and the environment. In contrast, organic mulch is a natural and biodegradable mulch that

Table 7. Economic efficiency of mulching by different mulching materials for two peanut cultivars

Mulching material	Peanut cultivar	Total revenue (VND/ha)	Total cost (VND/ha)	Net return (VND/ha)	Relative net return increase over control (%)
Non-mulching	L14	41,340,000	22,529,000	18,811,000	-
	L23	49,192,000	22,529,000	26,663,000	-
Clear plastic	L14	48,971,000	24,125,000	24,846,000	13.2
	L23	57,876,000	24,125,000	33,751,000	12.7
Rice straw	L14	47,892,000	20,825,000	27,067,000	14.4
	L23	56,784,000	20,825,000	35,959,000	13.5
Sugarcane bagasse	L14	46,774,000	21,125,000	25,649,000	13.6
	L23	56,147,000	21,125,000	35,022,000	13.1
Water hyacinth	L14	45,656,000	20,725,000	24,931,000	13.3
	L23	54,106,000	20,725,000	33,381,000	12.5

adds beneficial nutrients to the soil when composted. Organic mulches consist of plant residues, such as grass clippings, leaves, hay, straw, kitchen scraps, comfrey, shredded bark, whole bark nuggets, sawdust, woodchips, shredded newspaper, cardboard, wool, compost, and animal manure, etc. Organic mulches are cheap materials; therefore, the cost of mulching is also economical.

From such pros and cons of different mulching materials, this study also revealed that mulching is not only beneficial to peanut growth and yield but also results in economic efficiency with a higher net return of 12.5-14.4% than non-mulching. In addition, organic mulching provides additional value to soil in the form of nutrients. In the process of decomposing, organic mulches improve the soil's structure, drainage, and nutrient-holding capacity, and boost soil organic matter. Continuous use of organic mulches like straw, grasses, etc. improves the organic matter content of the soil, which in turn improves the soil water holding capacity (Agrawal *et al.*, 2010; Pedda Ghouse Peera *et al.*, 2020). However, the type of mulch to be used and its efficiency depend on the type of weed, type of soil/topography, prevailing weather conditions of the area, crop to be cultivated, and the availability of mulch. Thus, further studies on the application of organic mulching for peanuts over longer periods of time or covering more seasons should be conducted.

In the present research, mulching was conducted on sandy loam soils in the early spring cropping season when temperatures are typically low. Thus, mulching prevented rapid evaporation from the soil surface and maintained a higher soil temperature for better seed germination and early crop establishment. Plastic mulch was, in line with previous studies (Ramakrishnan *et al.*, 2006; Vu Ngoc Thang & Vu Dinh Chinh, 2007; Vu Van Liet *et al.*, 2010; Tran *et al.*, 2022), superior in creating a favorable microclimate for plant growth and yield formation. However, the organic mulches also significantly improved plant growth and pod yield and brought about higher benefits than bare soil cultivation (Vu Ngoc Thang & Vu Dinh Chinh, 2007). Among the organic mulches, rice straw was the most suitable/compatible in terms of its effects and efficacy with the ambient environment and the crop type. Rice straw is easily decomposable and can add a substantial amount of organic matter to the soil. Additionally, this study showed that the net return of rice straw application was the highest. Vu Ngoc Thang & Vu Dinh Chinh (2007) also indicated that rice husks brought about a higher net income compared to plastic mulch, maize stalks, and rice straw.

In upland crop cultivation, weeds are always a significant challenge and decrease crop productivity by interfering with crop growth. In this study, organic mulches effectively reduced weed composition and abundance, although less than clear plastic. Besides, mulching can also reduce pest populations (Zhu *et al.*, 2022). Previous reports have shown that different types and thicknesses of mulch have different effects on surface evaporation rates (Zribi *et al.*, 2015; Ye *et al.*, 2021). The thickness of rice straw, sugarcane bagasse, and water hyacinth applied in this study was 4cm. Gomonet & Cagasan (2020) assessed the thickness of rice straw and hull mulches at 2-5cm and reported that peanut mulched with rice straw at 5cm thick produced more pods per plant and the highest pod yield (2.64 tons/ha). Tran *et al.* (2022) applied 5cm thick rice straw resulting in a peanut yield of 3.26 tons/ha. Thus, compared with Gomonet & Cagasan (2020) and Tran *et al.* (2022), our study with 4cm thick organic mulches produced higher pod yields (3512-4368 kg/ha). Thus, it is evident that rice straw mulch was suitable for peanut cultivation on sandy or sandy loam soils. However, to exploit and enhance the effects of organic mulches in general and rice straw in particular, the thickness of organic cover could be varied, in the range of 2-5cm depending on local availability and soil properties to minimize evaporation and suppress weeds. In addition, the organic mulching materials could be chopped into smaller pieces for better land coverage. The different organic materials could also be combined to utilize the locally available resources for long-term soil health improvement.

Conclusions

Mulching materials, both inorganic and organic, had positive effects on peanuts in terms of plant growth, leaf area index, the number of nodules per plant, dry matter accumulation, weed suppression, yield components, yield, and net profit on sandy loam soil in the spring growing season in the coastal areas of Thanh Hoa province. In particular, rice straw provided the highest net return, followed by plastic and other plant residues. Thus, rice straw, with its widely availability, feasible cost, and significantly positive effects on peanuts, can be used as a mulching material for peanuts. Additionally, in the long term, the application of rice straw and plant residues will improve soil fertility and be an eco-friendly agricultural practice for sustainable peanut production.

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