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Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam

A. Ramakrishna [a,*], Hoang Minh Tam [b], Suhas P. Wani [a], Tranh Dinh Long [b]

[a] *Water, Soil and Agrobiodiversity Management, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru PO 502 324, Andhra Pradesh, India*
[b] *Legume Research and Development Center, Vietnam Agricultural Science Institute (VASI), Tranh Tri, Hanoi, Vietnam*

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Abstract

Groundnut (*Arachis hypogaea* L.) is one of the chief foreign exchange earning crops for Vietnam. However, owing to lack of appropriate management practices, the production and the area under cultivation of groundnut have remained low. Mulches increase the soil temperature, retard the loss of soil moisture, and check the weed growth, which are the key factors contributing to the production of groundnut. On-farm trials were conducted in northern Vietnam to study the impact of mulch treatments and explore economically feasible and eco-friendly mulching options. The effect of three mulching materials (polythene, rice straw and chemical) on weed infestation, soil temperature, soil moisture and pod yield were studied. Polythene and straw mulch were effective in suppressing the weed infestation. Different mulching materials showed different effects on soil temperature. Polythene mulch increased the soil temperature by about 6 °C at 5 cm depth and by 4 °C at 10 cm depth. Mulches prevent soil water evaporation retaining soil moisture. Groundnut plants in polythene and straw mulched plots were generally tall, vigorous and reached early flowering. Use of straw as mulch provides an attractive and an environment friendly option in Vietnam, as it is one of the largest rice growing countries with the least use of rice straw. Besides, it recycles plant nutrients effectively.

Keywords: Groundnut; Mulch; Soil moisture; Soil temperature

1. Introduction

Groundnut (*Arachis hypogaea* L.) is one of the main foreign exchange earning crops. It is also a good source of oil, protein and food for people; and fodder for cattle in Vietnam. However, the expansion of area under cultivation and the production of groundnut

* Corresponding author. Tel.: +91 40 30713071x2317; fax: +91 40 30713074/30713075.
E-mail address: a.ramakrishna@cgiar.org (A. Ramakrishna).

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have remained low owing to lack of high yielding varieties with suitable maturity period and improved agronomy (Ramakrishna et al., 1999).

More than 50% of the total agricultural land in Vietnam is used for the cultivation of rice (*Oryza sativa* L.). Continuous monocropping of rice; over-utilization of subsistence landholdings and its expansion to new, and often marginal farming areas; and non-adoption of appropriate soil, water and nutrient management practices are deteriorating soil fertility and quality, and increasing vulnerability of soil degradation. There is an urgent need to identify opportunities for crop diversification to break cereal monocropping.

Improved crop management through appropriate research and development is the only alternative to increase cropping intensity, since winter cropped area has stagnated in the potential regions like Red River Delta. In addition, spring rice is grown without irrigation on 2 million ha (out of total cultivated area of 6.5 million ha) with very low yields (1.5–2.0 t ha^{-1}) and this is another niche that offers good scope for expansion of area under groundnut (Chinh et al., 2001). However, appropriate management practices to combat low temperature (at maturity in autumn–winter and at germination in spring season) and terminal moisture stress hold the key for successful production of groundnut.

Mulches are known to increase the soil temperature since the sun's energy passes through the mulch and heats the air and soil beneath the mulch directly and then the heat is trapped by the ‘‘greenhouse effect’’ (Hu et al., 1995). Mulches also promote crop development and early harvest, and increase yields. Very little weed growth occurs under the mulch as the mulches prevent penetration of light or exclude certain wavelengths of light that are needed for the weed seedlings to grow (Ossom et al., 2001). Mulches greatly retard the loss of moisture from the soil. As a result, higher and uniform soil moisture regime is maintained reducing the irrigation frequency. An experiment, therefore, was designed and conducted for the first time in a farmer's field with the following objectives: (1) Assess the impact of different mulch treatments on groundnut productivity. (2) Understand the yield contributing factors and identify economically viable and environment friendly mulching options in northern Vietnam.

2. Materials and methods

The experiment was conducted during autumn–winter (September–December) 2000 and spring (February–May) 2001, on a highland region of northern Vietnam at Thanh ha watershed, Kim Boi District, Hoa Binh Province, which is about 70 km from south-west of Hanoi (20°39′N, 105°24′E, altitude 15 m). Thanh Ha watershed is the benchmark watershed of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the Vietnam Agricultural Science Institute (VASI) partnership project supported by the Asian Development Bank (ADB). Mean annual rainfall at Thanh Ha is 1300 mm and mean temperature is 25 °C, with an average maximum of 35 °C (in August) and an average minimum of 12 °C (in January). The soil is a well-drained red-yellow ferralitic, with the top 150 cm composed of 23% sand, 23% silt and 54% clay. Pre-sowing soil samples contained a pH of 4.7, 800 mg kg^{-1} total N (Kjeldhal method), 1.62 g kg^{-1} organic matter, 32 mg kg^{-1} available P (Olsen method) and 89 mg kg^{-1} available K (Kjeldhal method).

The experiment consisted of three-mulch treatments, viz., straw (SM), polythene (PM) and chemical (CM), and an unmulched control. All the treatments were replicated thrice in a complete randomized block design.

2.1. Land preparation and planting

Following ploughing, disc harrowing and ridging, newly released pod rot and bacterial wilt resistant semi-erect groundnut var. LO 2 was sown in plots of 6.0 m × 6.0 m. On 5 August 2000 (autumn–winter season) and 20 February 2001 (spring season), two seeds $hill^{-1}$ were dibbled in rows of 30 cm × 10 cm on broad beds of 1.5 m. On 15 December 2000 and 25 June 2001, an area of 3.0 m × 3.0 m from the center of each plot was hand harvested. In keeping with the practice of resource poor farmers in the region, a fertilizer application was prepared at the rate of 18 N kg ha^{-1}, 60 P kg ha^{-1} and 66 K kg ha^{-1} together with 0.4 t ha^{-1} lime at the time of sowing. The plants were subsequently thinned to retain one plant $hill^{-1}$ at 15 days after sowing (DAS). Observations recorded were (1) weed infestation, (2) soil temperature, (3) soil moisture and (4) yield and yield components at harvest. Plant observations were recorded on randomly selected five plants.

2.2. Mulching

Three mulching treatments and an unmulched treatment were applied. For polythene mulch treatment, a day after planting, transparent polythene film of 800–850 mm width with 0.009 mm thickness was spread uniformly in the polythene mulch (PM) plots. After a week, the seedlings were released by making a hole of 4–5 cm in diameter in the film over the seedling using three fingers, and 3–5 cm of moist soil was put on it to conserve moisture and temperature. The film was broken early in the morning (before 0900 h) to avoid exposure to the hot sun and seedling decay. The crop was inspected at four-leaf stage to make sure that no lateral branches are growing under the film, and in the case of non-emergence of any groundnut seeds, the gaps were filled with germinated seed.

For straw mulch (SM) plots 5 days after planting, 10 t ha^{-1} of rice straw was uniformly spread as a carpet manually. In recent years, new water soluble polymers have been introduced and are claimed to be of considerable economic and environmental advantages. Therefore, for chemical mulch (CM) plots, the new generation hydrophilic polymer available in the local market under the trade name NA-1® at 1 kg ai ha^{-1} was mixed in water (1000 l ha^{-1}) and sprayed uniformly on soil with the help of the knapsack sprayer.

2.3. Weed infestation

The occurrence, extent and types of weeds were studied at 30 DAS and at harvest in a 0.5 m^2 quadrat at three random locations per plot. All weeds in each quadrat were identified, counted and recorded for subsequent data analysis. Weed infestation was scored on a scale of 0–5; 0 represented total soil coverage by weeds and 5 represented none (Ossom, 1986; Daisley et al., 1988; Orluchukwu and Ossom, 1988). Weed infestation was also assessed by measuring dry weight per plot (Okugie and Ossom, 1988; Spandl et al., 1999). Relative abundance (RA) was calculated as the sum of relative frequency (RF), relative field uniformity (RFU) and relative mean field density (RMFD) for a given species (K):

$$RA_K = RF_K + RFU_K + RMFD_K$$

where frequency F is the percentage of the total number of plots surveyed in which a species occurred in at least one quadrat (Thomas, 1985); field uniformity FU is the percentage of the total number of quadrats sampled in which a species occurred (Thomas, 1985); main field density MFD is the number of plants m^{-2} for a weed species (Thomas, 1985).

The relative frequency (RF), relative field uniformity (RFU) and relative mean field density (RMFD) were calculated by dividing the parameter by the sum of the values for that parameter for all species and multiplying by 100. For example, the relative frequency for species K (RF_K) was calculated using

$$RF_K = \frac{\text{frequency value of species } K}{\text{sum of frequency values for all species}} \times 100$$

2.4. Soil moisture

The soil moisture was measured at 3, 30, 60 and 90 DAS up to 90 cm depth by gravimetric method (Black, 1965). The soil from different depths was sampled by manual coring and gravimetric moisture content (g/g) of the soil samples was calculated on oven dry weight basis and converted into volumetric moisture content (cm^3/cm^3) and then expressed as profile water content in 0–90 cm soil depth.

2.5. Soil temperature

Soil temperature at 5 cm and 10 cm depth was measured with stainless steel Fisher brand bi-metal dial thermometers having a stem length of 20.3 cm, gauge diameter of 4.5 cm, and accuracy of ±1.0% of dial range at any point of dial. Observations were recorded at 3 DAS; at flower initiation; beginning to seed and maturity stages at 0600, 1200 and 1800 h (in both mulched and unmulched plots). At each depth, two observations were taken; each from a different ridge of the same treatment. Soil temperature readings were taken at the west-facing side of the north-south ridges.

2.6. Biomass and pod yield

Groundnut is usually harvested at about 120 days in the uplands of northern Vietnam. In the present experiment, the crop was harvested between 120 and

135 days. Final shoot dry matter and pod yield were determined from an area of 3.0 m × 3.0 m in the center of each plot which was left undisturbed until the final harvest. The date of final harvest was estimated from visual observations of leaf senescence. Groundnut plants were uprooted and plant samples were then dried in a hot-air drier at 105 °C for 2 h followed by 80 °C for 36 h for moisture correction and then the pod yield was determined (Niu et al., 1998). Pods were air-dried for one week and then shelled. Dry weights of the seed and the shell were recorded after oven-drying.

2.7. Statistical analysis

Data was collected from sowing to harvest. The variables investigated were analyzed using Statistical Analysis Procedures (SAS, 1994). Fisher's protected least significant difference (LSD) test was used to detect mean differences between the treatments (Steel and Torrie, 1980).

3. Results and discussion

3.1. Weed infestation

Polythene and straw mulched plots compared to the chemical and unmulched plots showed significantly ($P \leq 0.05$) least weed infestation (Tables 1 and 2). At 30 DAS, the unmulched plots showed a greater diversity of weed species than the mulched plots. Weed scores at 30 DAS and at harvest also showed significant differences ($P \leq 0.05$). Plots mulched with polythene had the lowest number of invading weed species followed by straw mulch. At 30 DAS and at harvest, the unmulched plots showed a greater weed coverage than the polythene and straw mulched plots. Chemically mulched plots were better at 30 DAS only.

Weed dry mass at 30 DAS showed significant ($P \leq 0.05$) differences between the treatments. The polythene mulch gave the least weight (19 g m^{-2}) whereas the unmulched treatment gave the highest weight (63 g m^{-2}). At both 30 DAS and at harvest, chemically treated plots were covered with almost as many weed species as the unmulched plots, signifying chemical mulch to be ineffective in weed suppression. Polythene and straw mulch proved effective for weed suppression than the chemical and unmulched treatments. Daisley et al. (1988) and Ossom et al. (2001) also observed significant differences in weed control between mulched and unmulched plots of eggplant, cowpea and sweet potato.

3.2. Soil temperature

The polythene-mulched soil compared to chemical and unmulched treatments consistently had significantly higher temperature ($P \leq 0.05$) at 5 and 10 cm soil depths during both the seasons. On the other hand, straw-mulched soil when compared with chemical and unmulched treatments, recorded high temperature at all growth stages except at 0600 h in spring 2000 and at 30 and 90 DAS in autumn–winter (Tables 3 and 4). Mean soil temperature at 5 cm depth ranged from a high of 37.7 °C (3 DAS) to 25.0 °C (90 DAS) in polythene mulch to a low of 34.7 °C (3 DAS) to 21.6 °C (90 DAS) in unmulched treatments. While at 10 cm depth, the mean soil temperature ranged from a high of 33.1 °C (3 DAS) to 21.6 °C (90 DAS) in polythene mulch to a low of 30.9 °C (3 DAS) to 18.7 °C (90 DAS) in chemical and unmulched treatments. No significant differences in soil temperature were recorded among polythene and straw mulch treatments at both the soil depths. Generally, polythene mulch, followed by straw mulch, provided the highest soil temperatures. Again the range of temperature difference was narrower at 10 cm depth than at 5 cm depth for any selected date.

The high soil temperatures of mulched plots (straw and polythene) observed in this investigation were in agreement with the results of Choi and Chung (1997), who have observed that thermistors placed at soil surface recorded increase in soil temperatures by 2.8–9.4 °C and 0.9–7.3 °C at 5 cm depth. Increased soil temperatures observed in the mulched plots compared with the unmulched plots also agreed with the findings of Park et al. (1996) who observed an increase of 2.4 °C in average soil temperature at 15 cm depth under transparent film and an increase of 0.8 °C under black film. The findings of Duhr and Dubas (1990) showed an increase of 2.9–3.3 °C in soil temperatures with transparent, photodegradable polythene film mulching. Wheat straw mulch raised the soil temperature by 2–3 °C (Devi Dayal et al., 1991).

The results show that different mulching materials have varying effects on soil temperature. These are

Table 1
Effect of mulch on weed infestation in groundnut at 30 days after sowing (DAS)

Management practice/weed species	Family name	Relative abundance (%)	Weed score
No mulch			
Cynodon dactylon L.	Gramineae	12.8	3.4 a
Galinsoga parviflora Cav.	Compositae	11.6	
Eleucine indica L.	Gramineae	10.8	
Ageratum conyzoides L.	Compositae	4.3	
Euphorbia geniculata Ort.	Euphorbiaceae	3.6	
Amaranthus lividus L.	Amaranthaceae	2.8	
Erigeron sumatrensis	Compositae	1.9	
Echinochloa colona (L.) Link	Gramineae	10.6	
Digitaria ciliaris (Retz.) Koeler.	Gramineae	6.9	
Dactyloctenium aegyptium (L.) P. Beauv.	Gramineae	7.3	
Celosia argentia L.	Amaranthaceae	5.3	
Portulaca oleracia L.	Portulacaceae	7.9	
Legascea mollis Cav.	Compositae	7.3	
Chemical mulch			
Cynodon dactylon L.	Gramineae	16.8	2.6 b
Galinsoga parviflora Cav.	Compositae	14.9	
Eleucine indica L.	Gramineae	12.8	
Ageratum conyzoides L.	Compositae	8.5	
Euphorbia geniculata Ort.	Euphorbiaceae	4.8	
Amaranthus lividus L.	Amaranthaceae	7.6	
Digitaria ciliaris (Retz.) Koeler.	Gramineae	8.5	
Dactyloctenium aegyptium (L.) P. Beauv.	Gramineae	9.9	
Celosia argentia L.	Amaranthaceae	9.2	
Legascea mollis Cav.	Compositae	8.0	
Polythene mulch			
Cynodon dactylon L.	Gramineae	38.3	0.6 d
Galinsoga parviflora Cav	Compositae	22.9	
Celosia argentia L.	Amaranthaceae	21.2	
Legascea mollis Cav.	Compositae	17.6	
Straw mulch			
Cynodon dactylon L.	Gramineae	17.8	1.4 c
Galinsoga parviflora Cav	Compositae	14.6	
Celosia argentia L.	Amaranthaceae	15.2	
Legascea mollis Cav.	Compositae	11.6	
Eleucine indica L.	Gramineae	12.8	
Ageratum conyzoides L.	Compositae	11.9	
Euphorbia geniculata Ort.	Euphorbiaceae	7.7	
Amaranthus lividus L.	Amaranthaceae	7.3	
Mean	–	–	2.0
CV[a]	–	–	15.2
LSD[b] (0.05)	–	–	0.46

Means followed by the same letter within a column are not significantly different ($P \leq 0.05$).
[a] Coefficient of Variation (%).
[b] Least significant difference test ($P \leq 0.05$).

consistent with the results of Hanada (1991) who observed that polythene films (black, green or transparent) markedly increase soil temperature compared to grass mulch in temperate, sub-tropical and tropical regions. Dionne et al. (1999) observed that insulating material covers such as wood mat and straw affect the soil temperature, and the characteristics of protective soil covers also influence the soil temperature

Table 2
Effect of mulch on weed infestation in groundnut at 90 days after sowing (DAS)

Management practice/weed species	Family name	Relative abundance (%)	Weed score
No mulch			
Cynodon dactylon L.	Gramineae	6.7	1.8 a
Galinsoga parviflora Cav.	Compositae	13.6	
Eleucine indica L.	Gramineae	14.8	
Ageratum conyzoides L.	Compositae	11.6	
Euphorbia geniculata Ort.	Euphorbiaceae	6.6	
Digitaria ciliaris (Retz.) Koeler.	Gramineae	4.8	
Dactyloctenium aegyptium (L.) P. Beauv.	Gramineae	8.6	
Celosia argentia L.	Amaranthaceae	15.4	
Portulaca oleracia L.	Portulacaceae	9.3	
Legascea mollis Cav.	Compositae	8.7	
Chemical mulch			
Cynodon dactylon L.	Gramineae	11.8	1.5 a
Galinsoga parviflora Cav.	Compositae	15.9	
Eleucine indica L.	Gramineae	16.8	
Ageratum conyzoides L.	Compositae	12.5	
Sida acuta (Burm.).	Malvaceae	7.6	
Dactyloctenium aegyptium (L.) P. Beauv.	Gramineae	8.5	
Celosia argentia L.	Amaranthaceae	13.4	
Legascea mollis Cav.	Compositae	13.5	
Polythene mulch			
Cynodon dactylon L.	Gramineae	42.1	0.3 b
Galinsoga parviflora Cav	Compositae	14.9	
Bidens pilosa L.	Compositae	13.6	
Legascea mollis Cav.	Compositae	19.6	
Brassica chinensis L.	Cruciferae	9.8	
Straw mulch			
Cynodon dactylon L.	Gramineae	21.8	0.7 b
Galinsoga parviflora Cav	Compositae	17.6	
Celosia argentia L.	Amaranthaceae	13.2	
Legascea mollis Cav.	Compositae	9.6	
Eleucine indica L.	Gramineae	12.1	
Ageratum conyzoides L.	Compositae	8.9	
Euphorbia geniculata Ort.	Euphorbiaceae	5.7	
Sida acuta (Burm.).	Malvaceae	6.3	
Paspalum conjugatum Berg.	Gramineae	4.8	
Mean	–	–	1.07
CV[a]	–	–	18.2
LSD[b] (0.05)		–	0.65

Means followed by the same letter within a column are not significantly different ($P \leq 0.05$).
[a] Coefficient of Variation (%).
[b] Least significant difference test ($P \leq 0.05$).

variation ranges. Further, the present investigation shows that the polythene mulch offers better insulation than the other mulches and hence the increase in soil temperature. Usually, the polythene film used has a transmittance above 80%, and retains the sun's heat. Next in achieving the increased soil temperature was the rice straw, pointing to a possible benefit of this farm waste, which also helps in improving organic carbon content and nutrient supplying capacity of soils together with improvement in soil structure in the long run. Most farmers in Vietnam, unlike in other Asian counterparts, burn the rice straw because of limited farm cattle leading to environmental problems, i.e. releasing CO_2 into atmosphere.

Hanada (1991) indicated that mulching could have benefits on soils and the soil environment. Other reported benefits of mulch include microclimate and texture improvement, conservation of soil moisture and fertility, and the control of weeds, pests and diseases (Hu et al., 1995). Niu et al. (1998) showed that improved soil water and temperature with polythene mulches enhanced seedling emergence in spring wheat, while Hu et al. (1995) recorded earlier seedling emergence, improved crop growth and nodule development in groundnut. From these reports and highlighted benefits of mulch, it would be reasonable to expect that mulch applied in the present investigation attracted more benefits to the mulched plots than did the exposed soil of chemical and unmulched plots, thus enabling the mulched plots to show less weed infestation and increased soil temperatures.

3.3. Soil moisture

Evaporation from the soil accounts for 25–50% of the total quantity of water used (Hu et al., 1995). An important practice for rainfed agriculture, therefore, is to decrease evaporation of soil water. Mulch prevents soil water evaporation, and thus helps retain soil moisture. The monthly rainfall figures for the experimental period are given in Fig. 1. The rainfall patterns of both the seasons are different. Autumn–winter 2000 received 547.3 mm while spring 2001 recorded 785.7 mm of rainfall. In particular, 2000 is considered a low rainfall year with September as the wettest month receiving about 30% of the annual rainfall. The amount of moisture stored in the profile to a soil depth of 90 cm was significantly greater under

Table 3
Soil temperatures in mulch treatments at Vietnam during autumn–winter, 2000

Treatment	3 days after sowing			30 days after sowing			60 days after sowing			90 days after sowing		
	6 h	12 h	18 h	6 h	12 h	18 h	6 h	12 h	18 h	6 h	12 h	18 h
Soil temperature (°C) at 5 cm depth												
No mulch	33.2	35.3	35.6	31.2	32.8	33.2	28.2	29.3	29.6	21.2	21.9	21.8
Straw mulch	34.1	37.2	37.9	32.1	35.6	36.4	28.8	32.8	33.5	21.8	24.2	25.3
Polyethylene mulch	34.4	38.9	39.8	32.9	37.4	38.1	29.4	34.2	35.6	22.1	25.9	27.1
Chemical mulch	33.1	35.6	36.1	31.5	32.8	33.1	28.1	29.2	29.8	21.3	21.8	22.1
S.E.M.	0.32	0.83	0.95	0.38	1.13	1.23	0.30	1.26	1.47	0.21	0.99	1.28
CV%	1.92	4.51	5.11	2.35	6.52	7.01	2.10	8.03	9.12	1.96	8.42	10.65
Soil temperature (°C) at 10 cm depth												
No mulch	29.1	31.5	32.1	27.2	28.1	28.5	25.1	26.3	25.9	18.1	19.2	19.0
Straw mulch	29.5	32.8	34.2	27.6	30.2	30.9	25.5	27.5	28.1	18.5	21.1	21.9
Polyethylene mulch	29.8	33.9	35.6	28.1	31.9	32.2	25.9	28.1	29.2	19.5	22.3	23.1
Chemical mulch	29.0	31.6	32.2	27.1	28.2	28.5	25.1	26.2	25.5	18.0	19.1	19.0
S.E.M.	0.19	0.57	0.84	0.23	0.91	0.92	0.19	0.46	0.89	0.34	0.78	1.04
CV%	1.26	3.49	5.04	1.65	6.13	6.13	1.51	3.44	6.51	3.70	7.60	10.02

polythene and straw mulch over bare and chemically mulched soil (Fig. 2). For example, at 30 DAS, the polythene mulch plots contained more water (67 mm in autumn–winter and 47 mm in spring) than the unmulched plots, while straw mulched plots recorded more profile water content of 43 mm in autumn–winter and 37 mm in spring. Similar trend was noticed at 60 and 90 DAS while the difference in soil moisture storage was reduced. These figures also imply that greater moisture availability to mulched crop during the dry spells helped to cope better with terminal drought in autumn–winter and midseason drought at flowering in spring 2001. Chen (1985) also reported high water content in the top 5 cm of soil – an increase of 4.7% in clayey, 3.1% in loamy and 0.8–1.8% in sandy soil – with polythene mulch from sowing to the emergence of groundnut seedlings. During heavy rains, polythene mulch retards soil erosion, and rapid infiltration of rainwater into soil. Optimum soil moisture ensures good emergence and seedling growth.

As expected, the layer of polythene and grass mulch significantly reduced evaporation from the soil surface. Thus higher moisture content was always

Table 4
Soil temperatures in mulch treatments at Vietnam during Spring, 2001

Treatment	3 days after sowing			30 days after sowing			60 days after sowing			90 days after sowing		
	6 h	12 h	18 h	6 h	12 h	18 h	6 h	12 h	18 h	6 h	12 h	18 h
Soil temperature (°C) at 5 cm depth												
No mulch	25.6	26.8	26.9	26.9	28.5	29.6	29.5	31.1	31.5	31.6	33.4	34.1
Straw mulch	26.1	28.7	29.4	27.4	31.2	32.4	29.1	33.6	34.9	31.8	35.1	36.7
Polyethylene mulch	27.9	31.2	32.1	28.4	32.9	34.3	31.6	35.2	36.8	32.1	37.3	39.4
Chemical mulch	25.8	26.9	27.1	27.1	29.6	30.3	29.4	31.2	31.7	31.8	34.3	35.1
S.E.M.	0.53	1.03	1.22	0.33	0.96	1.07	0.57	0.99	1.29	0.10	0.83	1.16
CV%	4.00	7.26	8.42	2.43	6.28	6.73	3.83	6.06	7.63	0.65	4.76	6.37
Soil temperature (°C) at 10 cm depth												
No mulch	23.1	24.2	24.8	25.5	28.6	29.7	28.1	28.9	29.4	28.2	30.1	31.3
Straw mulch	24.3	26.2	26.8	26.1	29.1	31.5	28.9	31.2	32.1	28.8	31.9	32.6
Polyethylene mulch	25.2	28.1	28.5	27.2	30.8	32.9	29.6	32.6	33.8	29.1	33.6	34.9
Chemical mulch	23.2	24.6	25.1	26.6	28.4	29.6	28.1	28.8	29.6	28.1	30.4	31.8
S.E.M.	0.50	0.89	0.86	0.36	0.55	0.79	0.36	0.93	1.06	0.24	0.80	0.80
CV%	4.15	6.89	6.51	2.75	3.73	5.11	2.52	6.10	6.76	1.68	5.10	4.88

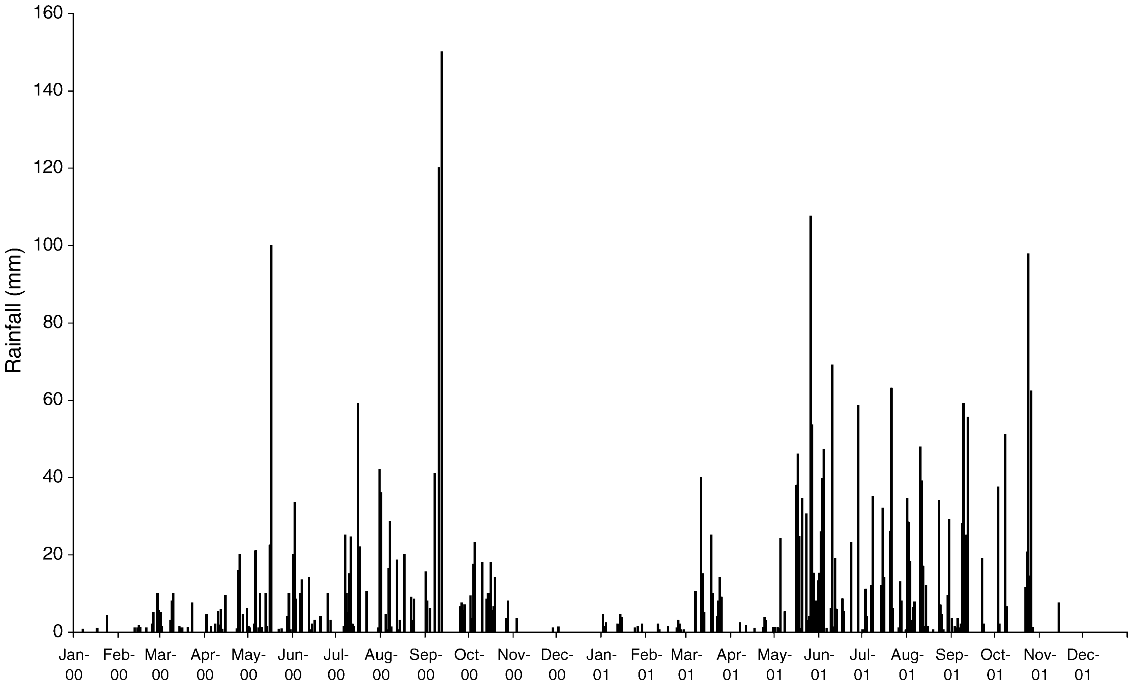

Fig. 1. Rainfall distribution during the experimental period.

observed in the 0–60 cm soil layer of the mulched plots compared to that of the unmulched plots (Fig. 2). This moisture difference ranged from 10% one or two days after rainfall to more than 22% over short periods of break in rainfall. These figures indicate that evaporation was high in unmulched plots. Extended droughts, however, lowered the moisture levels in both mulched and unmulched plots. The greater soil profile moisture under mulch has important implications on the utilization of water by crop and on soil reactions that control the availability of nutrients and biological nitrogen fixation (Surya et al., 2000). In a growing season, like spring 2001, when early rains are followed by a short-period of drought, the conditions in the top 30 cm of the soil, with respect to the availability of water and nutrients, will determine the survival of the young crop. This study has shown that within a period of 10 rainless days, the soil moisture on the surface and the upper subsoil of unmulched plots can be reduced from field capacity to wilting point or below, whereas the soil moisture in the mulched plot will remain well above the wilting range. Research has shown that mulch provides many benefits to crop production through soil and water conservation, enhanced soil biological activity and improved chemical and physical properties of the soil (Cooper, 1973). Adeoye (1984) recorded high moisture content up to a depth of 60 cm in grass-mulched soil together with good infiltration and reduced evaporation. Soil moisture in the polythene mulch at 60 DAS was 40.9–62.6% of the maximum field capacity and 9–10.9% higher than in unmulched soil. Water vapor flux density in the top 20 cm of the soil with polythene mulch was 1.7 times that of unmulch control, indicating greater movement of water from the deeper layers upward (Hu et al., 1995).

3.4. Crop yield

Polythene and straw mulch treatments increased the pod and stover yields of groundnut significantly over chemical and unmulched treatments in both the seasons (Table 5). The polythene mulched plots produced the highest yields—94.5% higher than the unmulched plots, 46.8% higher than the chemically mulched plots and 25.5% higher than the plots mulched with rice straw. There were variations in pod yield between the seasons, which probably can be

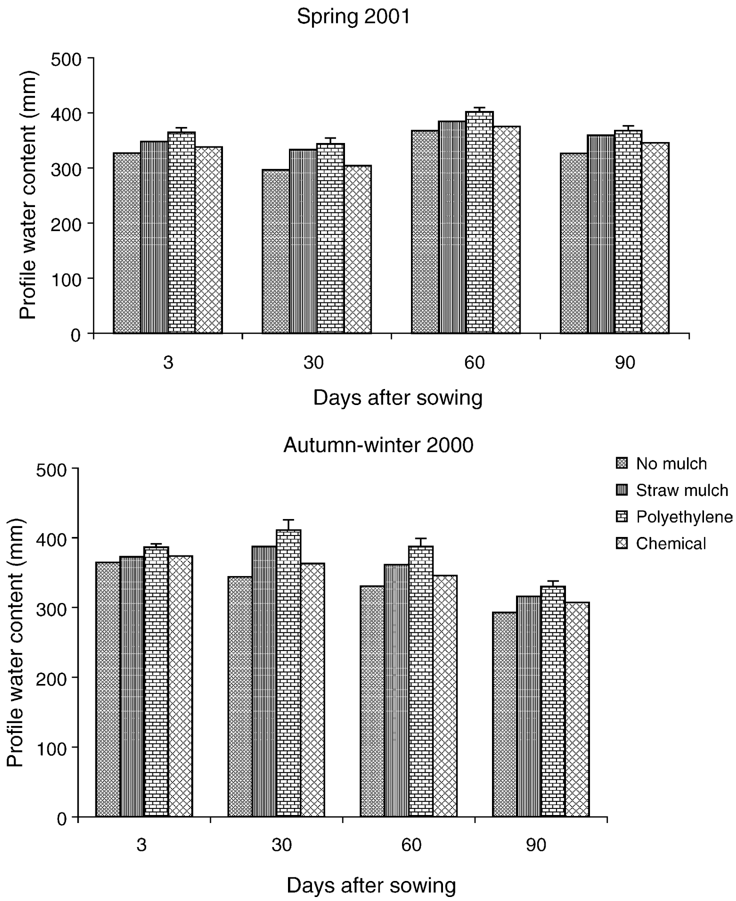

Fig. 2. Profile water content (0–90 cm depth) under mulched and unmulched ground.

partly explained by the pattern of rainfall amount and distribution. Observations showed that groundnut crop suffered because of some moisture stress during the first 4 weeks of growth in both the seasons of the experiment. Although seasonal rainfall in spring 2001 was high, the distribution was such that evapotranspiration exceeded rainfall during the early growth stages. Visual symptoms of moisture stress (leaf curl and wilt) were observed during the daytime in the groundnut of unmulched plots prior to 24.2 mm of

Table 5
Effect of mulch on groundnut yield and yield parameters in Thanh Ha watershed

Treatment	Pods plant^{-1}		Pod mass (g)		Test weight (g)		Pod yield (t ha^{-1})		Total dry matter (t ha^{-1})		Shelling (%)	
	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring
Unmulched	11.9	12.9	109.9	151.5	41.2	54.4	0.70	1.91	5.38	5.84	66.8	67.4
Straw mulch	13.6	13.7	113.7	155.1	43.8	58.1	1.18	2.68	5.88	6.40	65.8	69.2
Polyethylene mulch	14.5	15.0	118.1	156.2	46.2	61.2	1.54	3.23	6.32	6.88	68.3	69.3
Chemical mulch	14.1	14.3	108.7	154.1	42.6	56.3	1.03	2.24	6.14	6.10	66.7	68.1
S.E.M.	0.62	0.71	1.97	1.20	0.91	0.96	0.12	0.13	0.25	0.18	0.5	0.43
CV%	10	11	4	5	5	8	22	16	10	3	2	2

rainfall, which occurred on 5 May 2001. Groundnut leaves on straw and polythene mulched plots showed no visible effects of moisture stress.

Observations on plant growth showed that the groundnut plants in polythene and straw mulched plots were generally tall, more vigorous and reached 50% flowering 4–6 days earlier than in the unmulched plots. The more favorable soil environment under the polythene and straw mulch, especially during the early part of the growing season, resulted in increased number of pods plant^{-1}, pod mass, test weight and striking pod and stover yield increases. Devi Dayal et al. (1991) observed early flowering (by 5 days) in mulch treated groundnut crop. Hu et al. (1995) also reported increased crop growth (3.2–4.0 cm), dry root mass (12.2–50.1%), nitrogen-fixing activity (3.3–128.7%), chlorophyll content of the fresh leaves (41–78%) and more reproductive buds (63.3–94.1%) in polythene mulched plots than unmulched plots and thereby advanced peak flowering stage by 9 days. Grass mulching increased grain yield by 15–22% in maize and by about 10% in millet in northern Guinea and Sudan savanna regions of Nigeria (Adeoye, 1984). Cheong et al. (1995) observed highly positive correlation of proportion of sound seeds, 100-seed weight and shelling ratio with seed yield of groundnut and recorded 3.21 t ha^{-1} with clear polythene, 2.99 t ha^{-1} with black polythene and 2.31 t ha^{-1} without mulch in Iri, while Choi and Chung (1997) recorded more flowers, pegs, pods and kernels and greater 100-kernal mass in polythene mulched plots than on the unmulched plots in Suwon, Korea. Park et al. (1996) recorded seed yield increase in soybean by 18% with transparent film and by 15% with black film. Short stature and prostrate growth habit make groundnut a poor competitor with most weeds. Ramakrishna et al. (1991) reported that effective weed control resulted in improved yield parameters and yield of groundnut.

4. Conclusions

In northern Vietnam, the soils are slopy and the rains are short and intensive. Mulches check soil erosion and augment infiltration of rainwater into the soil. Polythene mulch, owing to its impermeability to hot air, ensures optimum temperature for the middle growth phase of groundnut. Besides, the reflection of sunlight by polythene film increases illumination between rows and wind speed. Polythene film does not allow the pegs developing during the later growth stages to enter the soil; thus saving nutrients for developing pods that were set earlier, increasing the number of well-filled pods and reducing the number of immature pods. The use of straw as mulch provides a more attractive option for farmers. The key factors that make straw mulch attractive are low cost (US$ 9.6 ha^{-1} as against US$ 94.5 ha^{-1} for polythene mulch and US$ 25 ha^{-1} for chemical mulch) and ease in availability and application. Organic mulches may also prove better in the long run as they improve soil organic matter and are environment friendly. However, disease build up and other interactions need to be studied before recommending straw mulch for wide adoption. Further research on the use of rice straw mulch in groundnut could provide valuable insights.

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