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Effect of tillage and mulching on the performance and status of some important soil properties on cultivating pigeon pea (*Cajanus cajan* L.)

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Abstract
A field experiment was conducted to assess the effect of tillage and mulching on the performance and status of some vital soil properties on cultivating pigeon pea. Yield attributes and yield like plant height, pod length, number of seeds per pod, stover yield and grain yield was observed and recorded.The study revealed that types of tillage did not have any significant effect on the recorded yield and yield attributes. Application of plastic mulch was found superior than control and other mulching materials in terms of plant height, pod length, number of seeds per pod, stover yield and grain yield. Addition of mulching materials also caused a progressive improvement in soil properties such as cation exchange capacity, bulk density, particle density, water holding capacity, mean weight diameter and percent aggregate >0.25 mm. The results from the study conducted demonstrate the status of the prominence of using mulching materials for different yield and yield attributing characteristics and improvement in soil properties.

Keywords: Tillage, mulching, yield and yield attributes, soil properties

Introduction
Pigeon pea is a popular source of vegetable protein in the human diet and in animal fed. The seeds contain 22.3% protein, 57.6% carbohydrate and 5% fiber and mineral. In addition to its value as a vegetable and animal feed, pigeon pea can be used as a source of fuel, green manure and as a soil erosion control agent. In India, pigeon pea is the second important pulse crop occupying 14% of the area and contributes 16% of the total pulse production. The water conservation practices like mulching and minimum tillage practices should be adopted in hilly region to protect the soil against degradation. Mulching is an important agronomic practice that not only prevents soil erosion by scattering kinetic energy of rain drops but also facilitates infiltration, reduces evaporation and improves soil structure which in due course enhances crop yield (Busari *et al*., 2015) [4]. Minimum tillage improves the soil physical properties as it improves the soil structure. Conservation tillage with maintenance of crop residue cover on 30 percent of the soil surface is soundly based within the frame work of conservation of natural resources and sustained production. Conservation tillage involving reduced tillage with mulching/residue management practices aims at preventing soil erosion, providing favorable soil and micro-climatic environment, reducing risks of pollution and minimizing environmental hazards. Conventional tillage includes ploughing twice or thrice, followed by harrowing and planking. It damages the soil structure and leaves no residues on the field. Minimum tillage is disturbing the soil to the minimum extent necessary so only primary tillage is done. In most cases, minimum tillage reduces soil loss by 30-40% over conventional tillage. The main objectives of minimum tillage are to conserve soil physical, chemical and biological aspects as well as soil moisture conservation by reducing the damage done by conventional tillage. Literature pertaining to effect of tillage and mulching on performance of pigeon pea and soil properties in Nagaland are very scanty. Therefore an attempt was made to study the effect of tillage and mulching on the performance and status of some important soil properties on cultivating pigeon pea.

Materials and Methods
A field experiment was carried out at the experimental farm of the Department of Soil and Water Conservation, SASRD, Medziphema Campus, Nagaland University during the *kharif* season of 2018-2019. Pigeon pea variety UPAS-120 was grown as a test crop.

The location of the experimental site was at 20^{0}45'43''N latitude and 93^{0}53'04''E longitude with an altitude of 310 m above mean sea level (MSL).
The experiment consisted of two factors –tillage as the main plot with two different types of tillage (T) i.e., minimum tillage (T_M) and conventional tillage (T_C) and the second factor consisted of five different mulching materials (M) i.e., M_0 – no mulch, M_{SD}– saw dust, M_{RH} – rice husk, M_{RS} - rice straw and M_P – plastic mulch. The experiment was carried out in a newly cleared forest land, following split plot design with four replications and ten treatments *viz*., T_MM_0 (minimum tillage+ no mulch), T_MM_{SD} (minimum tillage+ saw dust @5 t ha^{-1}), T_MM_{RH} (minimum tillage+ rice husk @5 t ha^{-1}), T_MM_{RS} (minimum tillage+ rice straw, T_MM_P (minimum tillage+ plastic mulch), T_CM_0 (conventional tillage+ no mulch), T_CM_{SD} (conventional tillage+ saw dust @5 t ha^{-1}), T_CM_{RH} (conventional tillage+ rice husk @5 t ha^{-1}), T_CM_{RS} (conventional tillage+ rice straw and T_CM_P (conventional tillage+ plastic mulch). For minimum tillage ploughing was done for seed sowing and for conventional tillage primary ploughing for seed bed preparation was done. Mulching materials *viz*. saw dust, rice husk, rice straw and plastic mulch was applied after germination. The fertilizer dose @ 40 kg N and 60 kg P_2O_5 were applied. The crop was sown at 2nd fortnight of July, with a spacing of 40 cm x 40 cm.
Prior to sowing of seeds, soil samples were collected from various locations of the experimental field at 15cm depth, to evaluate various soil properties. After harvest of the crop, soil samples were collected from individual plots and processed for analysis. The various soil properties were evaluated following standard procedures (Table 1).

Table 1: Initial soil properties of the experimental site

Soil parameters	Value
Cation Exchange Capacity {cmol (p^+) kg^{-1}}	9.60
Bulk density (g cm^{-3})	1.12
Particle density (g cm^{-3})	2.50
Water holding capacity (%)	57.23
Mean weight diameter (mm)	1.17
Percent aggregates (%)	89.27

Table 2: Soil properties and methods followed for determination

Soil properties	Methods employed	Reference
Cation Exchange Capacity {cmol (p^+) kg^{-1}}	NH_3 distillation method	(Jackson, 1973) [5]
Water holding capacity (%)	Keen Rackzowaski boxes	(Piper, 1996) [12]
Bulk density (g cm^{-3})	Pycnometer method	(Baruah and Barthakur, 1997) [2]
Particle density (g cm^{-3})	Pycnometer method	(Baruah and Barthakur, 1997) [2]
Percent aggregates (%)	Yoder's apparatus	(Van Bavel, 1949) [19]
Mean weight diameter (mm)	Yoder's apparatus	(Van Bavel, 1949) [19]

Results and Discussion
Yield and yield attributes
Plant height at harvest
The data for plant height at harvest is presented in (Table 3). The plant height under minimum tillage (174.13 cm) was slightly higher than conventional tillage (173.74 cm). Addition of different mulching materials and the interaction between tillage and mulching showed a significant effect in plant height as compared to control. The highest plant height was observed in plastic mulch (177.78 cm) and the lowest was recorded in control (169.21 cm). This resulted for an increase of 4.82% in plant height as compared to control. Jadav *et al*. (2020) [6] reported that addition of black plastic mulch recorded an increase in plant height of pigeon pea crop by over 11.9% as compared to no mulch plots. Similar finding was also reported by Solanki *et al*. (2019) [18]. Plastic mulch increased the plant height by about 8.57 cm as compared to control. Saw dust, rice husk and straw mulch resulted to an increase of 2.79, 1.80 and 4.01% plant height, respectively as compared to control.

Pod length
The pod length as influenced by tillage and mulching was recorded at harvest and is presented in (Table 3). The pod length under conventional tillage was slightly higher (0.34%) than minimum tillage. Addition of mulching materials and the interaction between tillage and mulching had a significant effect on pod length as compared to control (Table 4). Plastic mulch increased the pod length by about (0.70 cm) when compared with control. The highest pod length was observed in plastic mulch (6.11 cm) and the lowest was observed in control (5.41 cm). Application of sawdust, rice husk, rice straw and plastic mulch caused an increase of 7.95, 7.39, 8.69 and 12.93% pod length, respectively as compared to control. Kumar and Lal (2012) [9] reported an increase in yield attributing characteristics and crop yield due to addition of mulching materials. Similar findings were also reported by Bilalis *et al.* (2010) [3].

Number of seeds per pod
Types of tillage did not show any significant effect on number of seeds per pod (Table 3). Addition of plastic mulch caused a significant increase in number of pods per plant over no mulch and rice straw mulch treatments. The highest numbers of seeds were observed in plastic mulch (3.94) and the lowest in control (3.56). Singh *et al.* (2014) [16] reported that plastic mulch provides the best medium for improving different yield and yield attributes by regulating the soil moisture conservation and temperature of the soil, which is followed by crop residue mulch. Yield and other attributes in tomato were significantly increased by using black plastic mulch comparing to no mulch. This amounted to an increase of 10.67% number of seeds per pod as compared to control. Application of mulching materials like sawdust, rice husk and straw mulch increased the number of seeds per pod by about 3.65%, 4.49% and 0.84% respectively, as compared to control.

Stover yield
The types of tillage had no significant effect on stover yield (Table 3). Minimum tillage recorded higher stover yield (32.02 q ha^{-1}) over conventional tillage (30.48 q ha^{-1}). Addition of mulching materials and interaction between tillage and mulching had a significant effect on stover yield when compared with control. The highest stover yield was recorded in plastic mulch (34.11 q ha^{-1}) and the lowest in control (26.69 q ha^{-1}) (Table 6). Addition of saw dust, rice husk, rice straw and plastic mulch caused an increase of 21.28, 18.73, 17.65 and 27.80% stover yield, respectively as compared to control. Kumar and Rana (2008) [8] in a trial at IARI, New Delhi on effect of cropping system, moisture

conservation practice on pigeon pea found out that mulching increased the total dry matter production of cluster bean when compared to control. Similar trends were also reported by Singh *et al.* (2018) [17].

Grain yield

The data related to the grain yield are presented in Table 3 and 3b. The types of tillage had also no significant effect on grain yield. Addition of various mulching materials and the interaction between tillage and mulching had a significant effect on grain yield when compared with control. The highest grain yield was observed in plastic mulch (5.96 q ha^{-1}) and the lowest was observed in control (4.59 q ha^{-1}). Addition of mulching materials i.e. saw dust, rice husk, straw mulch and plastic mulch caused an increase of 22.22, 23.97, 24.84 and 29.85% grain yield, respectively as compared to control. Addition of mulching materials might have increased the soil moisture, temperature, soil organic matter and microbial activity which in turn increased the crop yield. Vijaymahantesh *et al*. (2013) [21] reported that weed dynamics and weed seeds are significantly reduced by tillage and soil depth which ultimately increase crop yield. Kishore *et al*. (2018) [7] stated that in the last decade, the use of plastic mulch has increased significantly in India due to its various benefits in protecting soil from erosion, conservation of moisture as well as increasing crop yield. Similar findings were also reported by Ashrafuzzaman *et al*. (2011) [1] and Verma *et al.* (2008) [20].

Soil properties

Cation exchange capacity (CEC)

The cation exchange capacity of the soil was not significantly affected by types of tillage (Table 5). The cation exchange capacity of the soil in various treatment combinations varied from 8.20 to 9.35 cmol (p^+) kg^{-1} (Table 6). Addition of mulching materials and the interaction between tillage and mulching had a significant effect on CEC as compared to control. The highest CEC was observed with the application of saw dust {8.99 cmol (p^+) kg^{-1}}, and the lowest with straw mulch application {8.21cmol (p^+) kg^{-1}}. Simsek *et al*. (2017) [15] reported an increase of about 18.79% in CEC in mulched plots as compared to no mulched plots.

Table 3: Effect of tillage and mulching on yield and yield attributes

Treatments	Plant height (cm)	Pod length (cm)	Number of seeds per pod	Stover Yield (q ha^{-1})	Grain yield (q ha^{-1})
Tillage					
T_M	174.13	5.80	3.69	32.02	5.54
T_C	173.74	5.82	3.71	30.48	5.50
S.Em ±	0.42	0.03	0.07	0.91	0.04
CD at 5%	NS	NS	NS	NS	NS
Mulching					
M_0	169.21	5.41	3.56	26.69	4.59
M_{SD}	174.08	5.84	3.69	32.37	5.61
M_{RH}	172.32	5.81	3.72	31.69	5.69
M_{RS}	176.28	5.88	3.59	31.40	5.73
M_P	177.78	6.11	3.94	34.11	5.96
S.Em ±	0.56	0.06	0.07	0.57	0.08
CD at 5%	1.63	0.18	0.21	1.67	0.23

Table 4: Interaction effect of tillage and mulching on yield and yield attributes

Interactions	Plant height (cm)	Pod length (cm)	Seeds per pod	Stover yield (q ha^{-1})	Grain yield (q ha^{-1})
T_MM_0	170.97	5.43	3.44	28.03	4.66
T_MM_{SD}	173.83	5.75	3.75	33.98	5.70
T_MM_{RH}	172.50	5.80	3.75	33.10	5.68
T_MM_{RS}	175.97	6.00	3.56	30.80	5.74
T_MM_P	177.36	6.04	3.94	34.23	5.91
T_CM_0	167.44	5.39	3.69	25.33	4.53
T_CM_{SD}	174.33	5.94	3.63	30.76	5.33
T_CM_{RH}	172.15	5.81	3.69	30.28	5.71
T_CM_{RS}	176.59	5.77	3.63	32.00	5.73
T_CM_P	178.21	6.18	3.94	34.00	6.02
S.Em ±	0.79	0.09	0.10	0.81	0.11
CD at 5%	2.30	0.26	0.30	2.36	0.32

Table 5: Effect of tillage and mulching on soil properties

Treatments	CEC {cmol (p^+) kg^{-1}}	WHC (%)	Bulk density (g cm^{-3})	Particle density (g cm^{-3})	Mean weight diameter (mm)	Percent aggregates (%)
Tillage						
T_M	8.67	57.39	1.13	2.58	1.32	87.92
T_C	8.84	56.63	1.12	2.61	1.29	87.19
S.Em ±	0.07	0.28	0.01	0.01	0.01	0.47
CD at 5%	NS	NS	NS	NS	NS	NS
Mulching						
M_0	8.90	50.25	1.17	2.48	1.19	84.88
M_{SD}	8.99	57.43	1.11	2.64	1.31	87.48
M_{RH}	8.94	57.58	1.15	2.63	1.31	87.35

M_{RS}	8.21	58.77	1.10	2.58	1.38	90.11
M_P	8.73	60.73	1.10	2.65	1.33	87.95
S.Em ±	0.13	0.42	0.02	0.02	0.02	0.65
CD at 5%	0.38	1.22	0.05	0.04	0.05	1.89

Table 6: Interaction effect of tillage and mulching on soil properties

Interactions	**CEC [cmol (p+) kg^{-1})]**	**Bulk density (g cm^{-3})**	**Particle density (g cm^{-3})**	**WHC (%)**	**MWD (mm)**	**Percent aggregates (>0.25mm)**
T_MM_0	9.00	1.20	2.41	50.50	1.19	86.75
T_MM_{SD}	8.63	1.10	2.65	57.48	1.29	86.70
T_MM_{RH}	8.75	1.14	2.62	57.75	1.35	87.05
T_MM_{RS}	8.20	1.10	2.60	59.05	1.43	90.40
T_MM_P	8.75	1.11	2.62	62.17	1.35	88.70
T_CM_0	8.80	1.14	2.55	50.00	1.18	83.00
T_CM_{SD}	9.35	1.12	2.63	57.38	1.34	88.25
T_CM_{RH}	9.13	1.16	2.64	57.41	1.28	87.65
T_CM_{RS}	8.23	1.10	2.56	58.50	1.33	89.83
T_CM_P	8.70	1.10	2.68	59.30	1.30	87.20
S.Em ±	0.18	0.03	0.22	0.59	0.03	0.91
CD at 5%	0.53	0.08	NS	1.73	0.08	2.67

Bulk density
The bulk density of the soil ranged from 1.10 g cm^{-3} to 1.16 g cm^{-3} (Table 6). Bulk density was not significantly affected by the types of tillage (Table 5). Addition of saw dust, rice straw and plastic mulch caused a significant decrease in bulk density as compared to no mulch treatment. Li and Huang (2013) [10] reported that deep tillage combined with mulching resulted in a decrease of bulk density in soil as compared to control plots. Similar finding was also reported by Rooper *et al*. (2013) [14]. Application saw dust, rice husk, straw mulch and plastic mulch caused a decrease of 5.13, 1.71, 5.98 and 5.98% bulk density, respectively as compared to control.

Particle density
The particle density of the soil was also not significantly affected by types of tillage (Table 5). The particle density of the soil ranged from 2.41 g cm^{-3} to 2.68 g cm^{-3} (Table 6). Addition of saw dust, rice husk, rice straw and plastic mulch caused a significant increase in particle density as compared to control. The interaction between tillage and mulching also had no significant effect on particle density. Similar findings were also reported by Pervaiz *et al.* (2009) [13].

Water holding capacity (WHC)
The types of tillage had no significant effect on water holding capacity of the soil (Table 5). Addition of mulching materials and the interaction between tillage and mulching had a significant effect on water holding capacity when compared with control. The highest WHC was observed with application of plastic mulch (60.73%) and the lowest in control (50.25%). This accounted to an increase of 20.85% WHC in plastic mulch as compared to control. Increase in water holding capacity of the soil with addition of mulching materials was reported by Mulumba and Lal (2008) [11]. Application saw dust, rice husk and straw mulch caused an increase of 14.28, 14.58, and 16.95% water holding capacity, respectively as compared to control.

Mean weight diameter (MWD)
The mean weight diameter of the soil was also not significantly affected by types of tillage (Table 5). Minimum tillage recorded an increase of 2.32% in MWD as compared to conventional tillage. Addition of mulching materials and the interaction between tillage and mulching had a significant effect on mean weight diameter as compared to control. The highest mean weight diameter was observed in application of straw mulch (1.38mm) and the lowest was in control (1.19mm). Straw mulch accounted for an increase in 13.76% in MWD as compared to control. Application of saw dust, rice husk, rice straw and plastic mulch, caused an increase of 10.08, 10.08, 15.97 and 11.76% in MWD, respectively as compared to control.

Percent aggregates >0.25 mm
The data related to percent aggregates is presented in (Table 5). Minimum tillage recorded a slight increase in percent aggregate (87.92%) as compared to conventional tillage (87.19%). Addition of various mulching materials showed a significant increase in percent aggregates as compared to control. The highest percent aggregate >0.25 mm was observed in straw mulch (90.11%) and the lowest in control (84.88%). Simsek *et al*. (2017) [15] also reported increase in aggregate stability with the application of straw mulch when compared with no mulch plot. This might be due to moisture conservation by mulching materials. Saw dust, rice husk, rice straw and plastic mulch accounted for an increase of 3.06, 2.90, 6.16 and 3.61% in percent aggregate, respectively as compared to control.

Conclusion
Based on the present results and discussion, it can be concluded that application of mulching materials had a positive effect on yield and yield attributes and improvement in soil properties. Minimum tillage on the other hand performed better than conventional tillage in many aspects by improving the soil physical condition. The use of plastic mulch may be recommended as in assessment to all the mulching materials used for this study, plastic mulching provided the preeminent response in the study conducted.

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