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Cover Page Footnote

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Robinia pseudoacacia leaves improve soil physical and chemical properties

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Abstract: The role of the leaves of *Robinia pseudoacacia* L., which is widely distributed in the arid lands, on improving soil physical and chemical properties was analyzed at various incubation periods. The incubated soils added with 0, 25, 50 and 75 g *Robinia pseudoacacia* leaves were tested after consecutive incubation intervals of 6, 8 and 10 months and the different soil parameters were measured. The results showed the increases in organic matter (OM), extractable K, cation exchange capacity (CEC), aggregate stability and water holding capacity, but the decreases in pH value and bulk density after 6 months' incubation. The gradual decrease in change rates of soil properties indicated less microbial population and organic residual mineralization under acidic conditions, which were resulted from fast decomposition of leaves after the first 6 months incubation. The increases in soil organic matter content, extractable K, CEC, aggregate stability and water holding capacity and the decreases in soil pH and bulk density provide favorable conditions for crop's growth.

Keywords: soil physical and chemical properties; *Robinia pseudoacacia*; Gilgit-Baltistan

1 Introduction

Robinia pseudoacacia L. is an important plant used for soil and water conservation (Wei *et al*., 2009). It was introduced in the Karakorum area in the middle of the 20th century when the Chinese government launched a large-scale tree planting campaign to reforest denuded mountains in the Loess Plateau. Robinia, also called as 'black locust', is considered to be a promising tree for reforestation due to its fast growth and ability to fix atmospheric nitrogen (Guo *et al*., 2005). It also works effectively in soil and water conservation and environmental protection in arid areas. It can significantly improve soil properties; especially increase soil nitrogen level since the tree is a nitrogen fixing plant. It has been estimated that *Robinia pseudoacasia* can add up to 75 kg N/(hm^2·a) (Boring and Swank, 1984; Liu and Deng, 1991; Olesniewicz and Thomas, 1999). Wei *et al*. (2009) indicated that a twenty-one year's growth of black locust increased soil organic matter and nitrogen stocks by 24.65 t/hm^2 and 0.66 t/hm^2 respectively and reduced soil phosphorus stock by 2.41 t/hm^2 at 0–80 cm soil layer. Organic matter is decomposed into CO_2 and several acids, which eventually produce H^+ to soil solution and thus, significantly reduce soil pH (Khattak, 1996). Addition of organic matter reduces the bond of K from liable pool, and thus increases extractable K in soil. It is also well known that organic matter has a higher cation exchange capacity (CEC) and total CEC of soil depends upon its organic matter content (Alexander, 1992). The positive correlation between organic matter and CEC of the soil was reported by Khattak (1996). Addition of organic materials to soil stimulates the formation and stabilization of crumb aggregates (Emerson, 1986). The long term aggregate stability is normally offered by cementing action of stable humus components, which has unexcelled capacity to hold water and absorb cations. The stable aggregate helps to improve soil structure and keeps soils sustainably productive (Stevenson, 1982; Brady, 1990). Soil organic material is essential for soil aggregate formation, maintaining porosity and reduc-

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ing bulk density (Stevenson, 1986). The present study was conducted to clarify the effect of *Robinia pseudoacacia* leaves on soil physical and chemical properties and to evaluate its potential as organic fertilizer for sustainable agriculture on arid and semi arid agricultural lands.

2 Study area and methods

2.1 Study area

The Gilgit-Baltistan, formerly called Northern Areas of Pakistan, encompasses an area of 72,496 km^2 and is the home of over 1.5 million people. It borders internationally with the Xinjiang Uyger Autonomous Region of China, Wakhan corridor of Afghanistan, and India. Gilgit is the administrative capital of Gilgit-Baltistan. Being in the mountainous landscape among the great mountain ranges of Himalayas, Karakoram, and Hindu Kush, Gilgit is situated almost above 3,000 m a.s.l. The climate of the region varies widely ranging from the monsoon-influenced moist temperate zone in the western Himalayas to arid and semi-arid cold desert in the northern Karakoram and Hindu Kush. Below 3,000 m, the annual precipitation is less than 200 mm. However there is a sharp precipitation gradient along the altitude, and over 2,000 mm annual snowfall was observed above 6,000 m a.s.l. The temperatures in the valley bottoms vary from extreme 40ºC in summer to less than –10ºC during winter. The valley has a good patch of dry temperate pine and broad leave forests with a mix of robinia, poplar and willow trees. However, among non forest trees, *Robinia pseudoacacia* are most commonly distributed in the study area.

2.2 Soil sampling

Soil samples were collected according to the standard technique given in the BARD Manual (Jankee *et al*., 1980) at the beginning of the study. Fifty samples were collected randomly from the furrow slice (12 cm depth) using soil augur. Collected samples were air-dried, mixed to prepare a composite sample, ground lightly and sieved through 2 mm mesh. Then the sample was stored in polythene bags, tagged with key information for future usage.

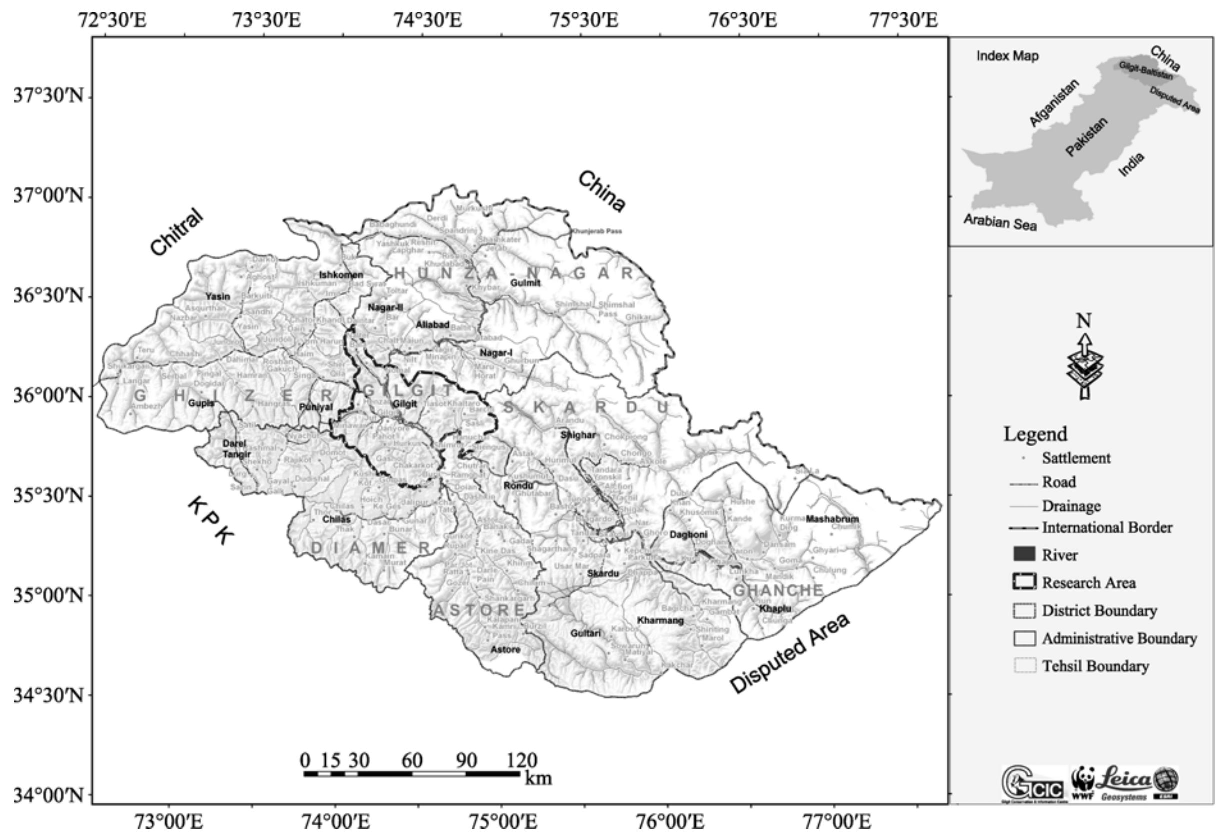

Fig. 1 Map of Gilgit-Baltistan (Pakistan)

2.3 Pre incubation analysis

Before subjecting the sampled soil to *vitro*-cultural incubation, the samples were measured for various physical and chemical parameters such as texture (sand, silt and clay), organic matter content, pH, cation exchange capacity, extractable K, aggregate water stability, water holding capacity, and soil bulk density using standard methods given in the U. S. Department of Agriculture (1954). The results showed that the soil texture was composed of sand (67.36%), silt (18.00%) and clay (14.64%). Other parameters such as the organic matter content was 1.58%, pH 7.06, CEC 0.328 mmol/kg, extractable K 74.32 μg/g, aggregate water stability 40%, water holding capacity 2.02% and soil bulk density 1.21 g/cm^3.

2.4 Experiment design

Freshly fallen leaves of *Robinia pseudoacacia* were collected from the local robinia trees in autumn, air dried for six days and milled with hands. There were 12 treatments and each treatment had three replicates in this study. The treatments were a 500 g sampled soil each mixing with 0, 25, 50, and 75 g milled robinia leaves, respectively and incubated for 3 different periods. Each treated soils was properly filled into a pot and all the pots were incubated at room temperature (20–25°C) for 6, 8 and 10 months. All the pots were maintained soil moisture of the field capacity level and stirred twice a week to ensure optimum moisture and aeration for mineralization throughout the study period.

2.5 Data analysis

The results were analyzed using Excel 2007 for simple calculations, graphics and interpretation (McCullough and Heiser, 2008) and the statistical analysis was performed using MSTAT-C software (Michigan State University, USA) in the Randomized Complete Block Design (RCBD) for factor A (incubation period) and factor B (quantity of leaves), a split plot on A. Correlation and analysis of variance (ANOVA) were performed to reveal the relationships among different soil properties and to test difference of soil properties as affected by incubation periods and varying quantities of robinia leaves, respectively. The means were separated by least significant difference (LSD) test at 5% level.

3 Results and discussion

3.1 Effect of *Robinia pseudoacacia* leaves on soil organic matter content

An initial inclining but eventually a schematic declining in the organic matter (OM) after 8 and 10 months' incubation was shown in Fig. 2a. This initial increase in OM followed by a gradual decrease reflects the organic material mineralization process, which could be attributed to the formation of humic, fulvic and carbonic acids in the soil during the 6 months incubation period as a result of rapid decomposition of the added organic matter. However, the later fall in OM after 8 and 10 months might be due to prevailing acidic conditions that adversely affect microbial populations and thus slowing down their activity. Our results are fully in line with the findings of Khan and Saeed (1996) and Wei *et al*. (2009).

3.2 Effect of *Robinia pseudoacacia* leaves on soil pH

Figure 2b indicates a decrease in pH both with increasing amount of *robinia pseudoacacia* leaves and prolong incubation periods. However, the pH change rate of 6 months' incubation period was higher than those of 8 and 10 months' incubation periods, which could be due to formation of acids in the soil as a result of rapid mineralization during the first 6 months followed by a slower decomposition during later incubation periods.

3.3 Effect of *Robinia pseudoacacia* leaves on soil extractable potassium

The results of 6 months' incubation revealed a gradual increase in soil extractable K with increasing quantity of leaves (Fig. 3a). This might be due to an enhanced mineralization process, which was stimulated by carbonic acid and other strong organic and inorganic acids formed during organic materials mineralization process (Cassman, 1992). The increased rates of 8 and 10 months' incubations were less than that of the 6 months' incubation, which seems due to a less microbial activity in acidic conditions and fixation of K into the inner layer spaces of clay lattice from the organic pool (Jia and Guan, 1993).

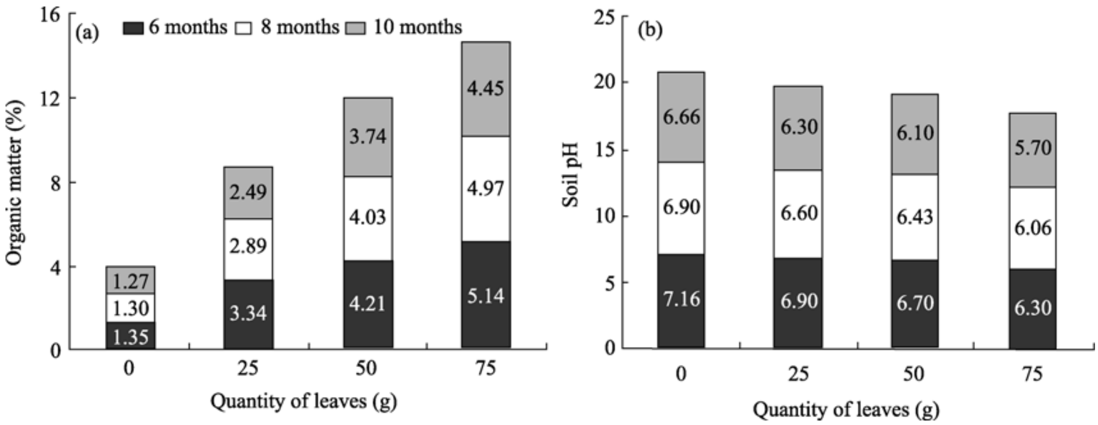

Fig. 2 Effects of robinia leaves on organic matter content (a) and soil pH (b)

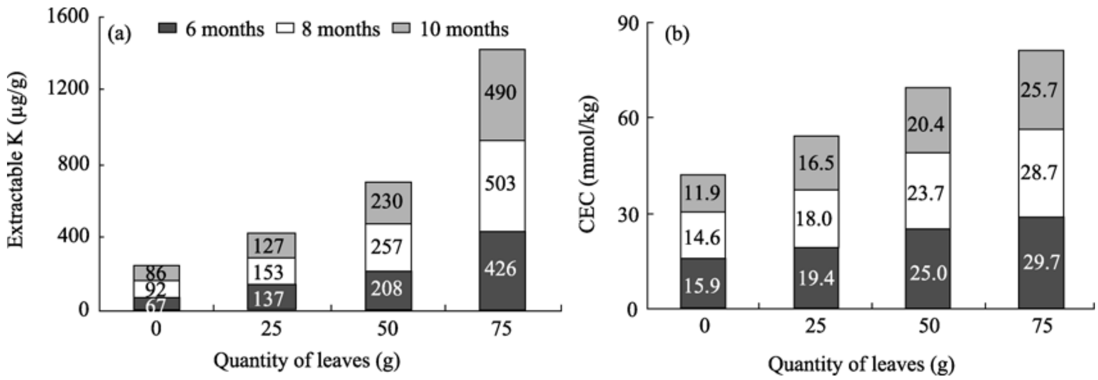

Fig. 3 Effects of robinia leaves on extractable K (a) and CEC (b)

3.4 Effect of *Robinia pseudoacacia* leaves on cation exchange capacity

CEC is normally used for assessing the availability of soil exchangeable cations for plants utilization (Khattak, 1996). The experimental results showed that the CEC increased both with the increasing quantity of leaves application and the incubation period (Fig. 3b). This increase is probably due to colloidal form of humus having more specific surface area for cations adherence (Alexander, 1992; Hussain *et al*., 1999; Annan *et al*., 2005; Jozefaciuk *et al*., 2006).

3.5 Effect of *Robinia pseudoacacia* leaves on aggregate water stability

The experimental results show a significant increase in aggregate stability with increasing amount of robinia leaves (Fig. 4a). This was also observed by Emerson (1986). The rapid increase in the aggregate stability of six months' incubation and increase in organic material residue of the 8 and 10 months' incubation indicates a gradual decline in the mineralization of organic residues under acidic conditions of the soil. The results are in agreement with the findings of Stevenson (1982) and Brady (1990).

3.6 Effect of *Robinia pseudoacacia* leaves on water holding capacity

The experimental results showed a dramatic increase in soil moisture holding capacity with increasing quantity of leaves and the length of incubation period (Fig. 4b). A consistent increase in soil moisture holding capacity was observed throughout the incubation period, and this might be due to an increase in soil micro porosity, which was resulted from rapid decomposition of organic matter. After 10 months' incubation, soil water retention capacity was further increased, but its rate was less than before. This result implied a less mineralization of organic matter and limited soil micro porosity, which is in agreement with the findings of Anwar (1992) and Brady (1992).

3.7 Effect of *Robinia pseudoacacia* leaves on soil bulk density

Soil bulk density is one of the key factors related directly with soil weight bearing potential, and indirectly

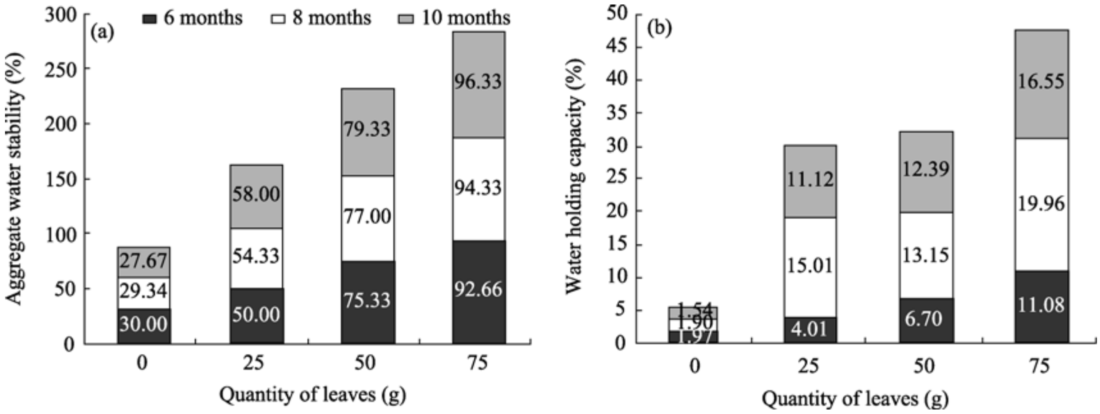

Fig. 4 Effects of robinia leaves on aggregate stability (a) and water holding capacity (b)

with crop production and growth processes (Stevenson, 1986). As shown in Fig. 5, the soil bulk density has decreased fast both with increasing amounts of leaves and the length of incubation periods. The decrease in bulk density was particularly clear in 6 months' incubation treatment. While comparing the trend, a slightly increasing pattern in soil bulk density was observed

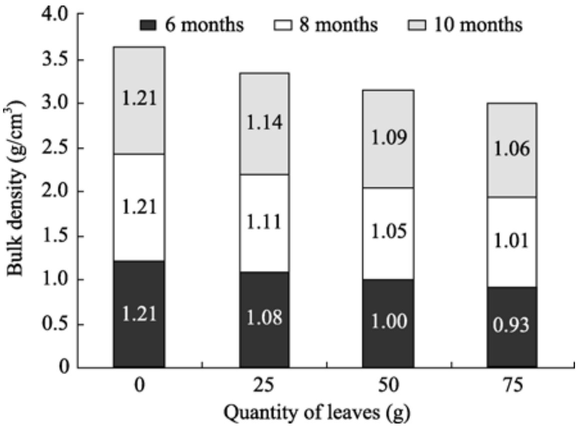

Fig. 5 Effect of robinia leaves on bulk density

Table 1 Results (*F* values) of the two-way analysis of variance for incubation periods and *Robinia pseudoacacia* leaves addition treatments (n = 36)

Parameters	Incubation periods	Quantity of leaves	Incubation period × quantity of leaves
Organic matter	40.14	880.90	2.34
pH	40.67	41.56	0.108^{NS}
Extractable K	5,027.39	13,0901.31	434.27
Cation exchange capacity	3,608.76	3,328.60	6.16
Aggregate water stability	19.90	1,472.28	2.91
Bulk density	111.93	341.42	11.23

Note: all treatment means vary significantly at $P < 0.05$ except for the value of 0.108.

in 8 and 10 months' incubation treatments. This could be attributed to the rapid mineralization of bulky materials leading to soil porosity reduction. This was also shown by Bhatti and Taggar (1989) and Wei *et al*. (2009).

3.8 Correlation among the soil chemical characteristics

The results revealed a strong positive correlation of OM with extractable K (r = 0.8914), and CEC (r = 0.9571), whereas, a strong negative correlation of OM with pH (r = –0.9547) and soil bulk density (r = –0.9963). Similarly, extractable K was positively correlated with CEC (r = 0.9568) but negatively correlated with pH (r = –0.9854). A strong negative correlation was observed between pH and CEC (r = –0.9857) and a strong positive correlation between pH and soil bulk density (r = 0.9697). The results were closely in line with Hussain *et al.* (1999), Babar *et al.* (2004), Annan-Afful *et al*. (2005), Jozefaciuk *et al*. (2006) and Wei *et al*. (2009).

4 Conclusions

Robinia pseudoacacia leaves had a significant effect on various soil physical and chemical properties. The organic matter, cation exchange capacity, aggregate water stability, and water holding capacity considerably increased with the addition of robinia leaves. However, the soil pH and bulk density decreased when soil was mixed with robinia leaves. Adequate amount of organic matter (>1.0%), high CEC, better soil structure, high water retention capacity, slightly acidic soil

soil conditions (depending on soil pH) and lower bulk density are normally optimal soil conditions for many crops and ensure a high crop productivity. In Gilgit-Baltistan farming area, it takes 6 to 8 months for *Robinia pseudoacacia* residues to be decomposed and release optimal nutrients into the soil. Therefore, applying adequate *Robinia pseudoacacia* leaves at least once in a year is suggested for sustainable productivity arid and semi arid agricultural lands similar to Gilgit-Baltistan.

Acknowledgements

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