The effect of peach-soybean intercropping system with straw mulching on N and P losses, surface runoff in Dianchi Lake watershed mountain area, Yunnan province, China

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Abstract. Field experiments were conducted with peach (local variety)-soybean intercropping system as an agro-forestry community. The results showed that the reduction rate of COD_{cr} losses were 24.31%, 50.50% and 65.19% respectively under the precipitation strength between 25mm d^{-1} and 100 mm d^{-1} with treatments of 36 kg $plot^{-1}$, 54 kg $plot^{-1}$ and 72 kg $plot^{-1}$ straw mulching. The reduction rate of NH_4^+-N losses were 12.56%, 49.38% and 58.60%, respectively; The reduction rate of NO_3^--N losses were 27.78%, 9.55% and 58.61%, respectively; The reduction rate of TN losses were 3.85%, 31.67% and 56.01%, respectively. The reduction rate of TP losses were 23.02%, 30.19% and 42.65%, respectively. The yields of soybean increased by 24.09%, 47.46% and 93.84%, respectively. Peach-soybean intercropping with straw mulching could decrease the runoff losses of nitrogen and phosphorus with time effect for reducing non-point sources pollution losses.

1 Introduction

Straw mulching is referred to a way of farming that covers crop straws on the surface farmland. It plays an important role in reducing strike, elution and lash by heavy rain, so that the structure and function could be maintained well and in case soil erosion and water loss [1-3]. Straw mulching also can increase the activities rate of saccharase, alkaline phosphatase and urease by 46.9%, 9.0% and 390%. Straw mulching promotes water and fertilizer utilization around plants' rhizosphere and strengths soil enzyme's role of migration, decomposition and transformation in ecosystem [5,6].

Various factors influence non-point sources pollution, while the rainfall was one of main source of soil erosion and water loss. The rain strengthen was closely associated with surface runoff and losses. The greater the rainfall intensity was, the longer the duration lasted, the more the loss of nitrogen and phosphorus in surface runoff increased [7]. When the rainfall intensity is high, lots of total phosphorus enrich and loss with surface runoff. In contrast, nitrogen and phosphorus could be loss with two types of water soluble and particulate [8-11]. Straw mulching has good effects of soil and water conservation and improves soil fertilizer. It significantly decreases soil erosion and sediment loss in surface runoff, increases the content of nitrogen in surface soil and promotes absorption of soil nutrients for crops. Relative researches showed that straw mulching decreased surface runoff and sediment by 5.31% and 94.09%, decreased the loss of COD, total nitrogen and total phosphorus by 48.10%, 59.25% and 79.60% [12], decreased the loss of ammonia nitrogen by 16.1% - 83.1% [13,14]. Furthermore, straw mulching also significantly decreased the nitrogen loss and fertilizer effect was positive correlation with its quantity.

This research was aimed to understand the effects of peach-soybean intercropping system with straw mulching on losses of surface runoff in Dianchi lake watershed mountain area and provide references for agricultural solid waste utilization.

2 Materials and methods

Study material. *Leguminosae Tephrosia* Mill.Var."Xianboshi218", *Amygdalus persica* L. Mill.Var."Yanhong" and maize straws were selected as experimental materials. The common compound fertilizer was used for fertilizing (N：P_2O_5：K_2O: 13:5:7).

Study site. Study area was located in Caojiachong village, Dabanqiao Town, near Kunming city, Yunnan Province (24°2′5.0″N, 102°64′28.0″E, 2044 m).These areas are slope farmland, which are subtropical monsoon climate in Dianchi lake watershed. The annual rainfall was about 953 mm, with distinct wet and dry seasons. The rainy season is mainly from May to October, which produce >80% of annual precipitation. Its annual mean temperature is 14.7 °C, and the annual sunshine hours are about 2200 with southwest slope. Soil type is lateritic red

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soil in Chinese and kanhapludults in USDA taxonomy [14]. The soil was clay loams, parent materials are sandy shale, and the geological period is Triassic, which is relatively rich in P [15]. Soil background properties were 1.68 g kg^{-1} (0.17%) total nitrogen, 0.15 g kg^{-1} (0.02%) total phosphorus, 8.63 g kg^{-1} (0.86%) **total potassium**, 13.71 g kg^{-1} (1.37%) organic matter, 14.35 mg kg^{-1} **available nitrogen**, 24.6 mg kg^{-1} **available phosphorus**, 103.95 mg kg^{-1} **available potassiums** and 7.12 pH value.

Experimental design. **Fifteen plots were designed on slope farmland with** randomized block arrangement. Each standard experimental plot measured 5 × 12 m (16.4 × 39.4 ft). Each plot was surrounded as regular **rectangle by** asbestos tile. A 70 cm deep pit was dug on the left bottom of plots within a 61.5 cm **cylindrical** polyethylene plastic bucket. Then PVC water pipes were laid on the left of plots to collect the surface runoff flowing into bucket through pipes. The soybean's seeds were sown into ground in 2 June, 2015. The line spacing of seeds was 30 cm, row spacing was 20 cm with isolation strip. The maize straws were mulched in 16 June. The maize straws were cut as 50 cm long, covering the amount of 36 kg $plot^{-1}$, 54 kg $plot^{-1}$ and 72 kg $plot^{-1}$. Non straw mulching was as control. The amount of runoff on the experimental site was recorded for 12 hours after each rainfall event, including eight times in 15 June, 2015, 24 June, 18 July, 10 August, 12 August, 20 August, 26 August and 27 August. Soybeans were harvested in 2th September.

Measurement of runoff and export of nutrients. Total N was assayed using the potassium supersulphate oxidation-ultraviolet spectrometer method. Total P was assayed using the ammonium metamolybdate spectrophotometric method (GB11893-89) (Eisalou et al. 2013; Lowrance et al. 2007). Ammonia nitrogen was determined by Nessler's reagent colorimetric method (HJ535-2009). **Nitrate nitrogen** was determined by pbenoldisulfonic acid **spectrophotometry** (GB7480-87**).** Nutrient export was calculated using the following equation: Amount of nutrient export (mg m^{-2}) = [nutrient content (mg L^{-1}) × amount of runoff (L)]/ size of sampling plot (m^2).

Statistical analysis. Significant difference was tested using single factor Analysis of Variance ($p < 0.05$), and correlation analyses were performed using SPSS 16.0 ($p < 0.05$, $p < 0.01$).

3 Results and discussion

3.1 Precipitation characteristics

The total precipitation was 1106 mm from May to September, with 278 mm in May, 239 mm in June, 292.4 mm in July, 199.8 mm in August and 96.8 mm in September, 2015 (figure 1). From May to September, there were 138 times rainfalls, which met to normal distribution with heavy rain concentrated in July and August. Base on the National Weather Rainfall Strength Taxonomies (China) during May and September, there were 6 times with rainfall strength ≤ 10mm d^{-1} (small rain), 61 times with 10 < rainfall strength ≤ 25mm d^{-1} (median rain), 10 times with 25 < rainfall strength ≤ 50mm d^{-1} (heavy rain) occupied 44.20% of total precipitation, 10 time with 50 < rainfall strength ≤ 100mm d^{-1} (rainstorm) occupied 7.25% of total precipitation (figure 1). The rainfall strength could influence losses rates and formation of the surface runoff, N and P [11]. Loss rates of N and P increased with increase in rainfall strength and last time [7]. The TP loss dominated companying with sediment loss when median and heavy rain happened, and the loss formation of N and P was mainly water soluable and particulate combined with sediment when small rain happened [8-10].

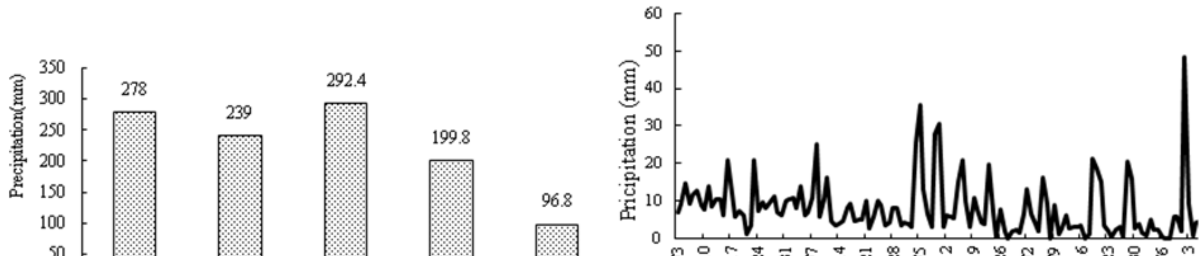


Fig. 1. The month and day characteristics of precipitation at study site in 2015.

3.2 Effects of straw mulching on CODcr loss of surface runoff

The maxmium losses of CODcr with non-treated plots with heavy rain were 0.79 kg hm^{-2} and 0.77 kg hm^{-2} at 3 August and 28 August. The maxmium losses of CODcr with 72 kg $plot^{-1}$ straw mulching with heavy rain reached to 0.31 kg hm^{-2} at 30 July and 6 August. Compared with non-treated plots, the total reduction rate of CODcr with 36 kg $plot^{-1}$, 54 kg $plot^{-1}$ and 72 kg $plot^{-1}$ straw mulching was 24.31%, 50.50% and 65.19%, respectively (figure 2). Some researches reported that the runoff coefficient reduced by >97% and surface runoff and erosion decreased by >80% with straw mulching [16,17]. Straw mulching could reduce the directly shocking, leaching of rain to soil surface, which decreased by 55.31% surface runoff, 94.09% sediment, and 48.10% COD [12]. Soil function and fertility could be improved, including increase in contents of organic matter, soil aeration and soil porosity and decrease in soil bulk density with straw mulching [2].

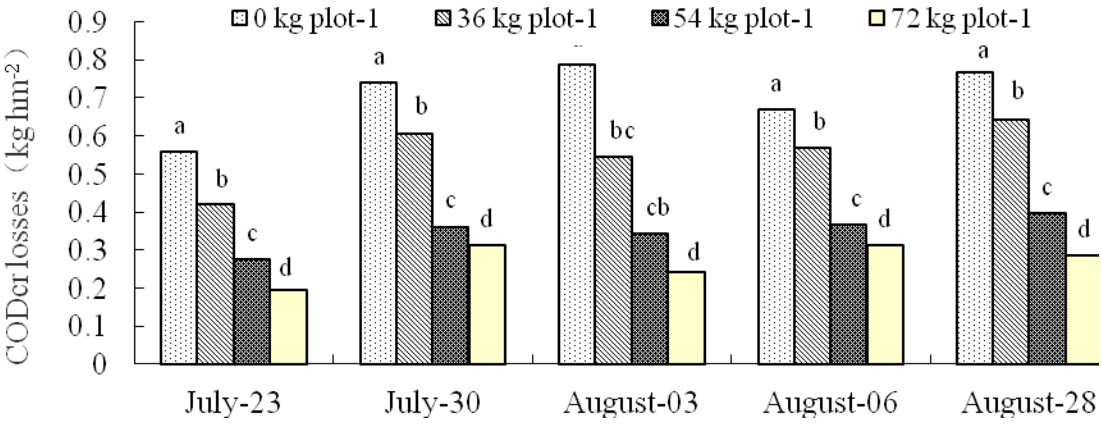
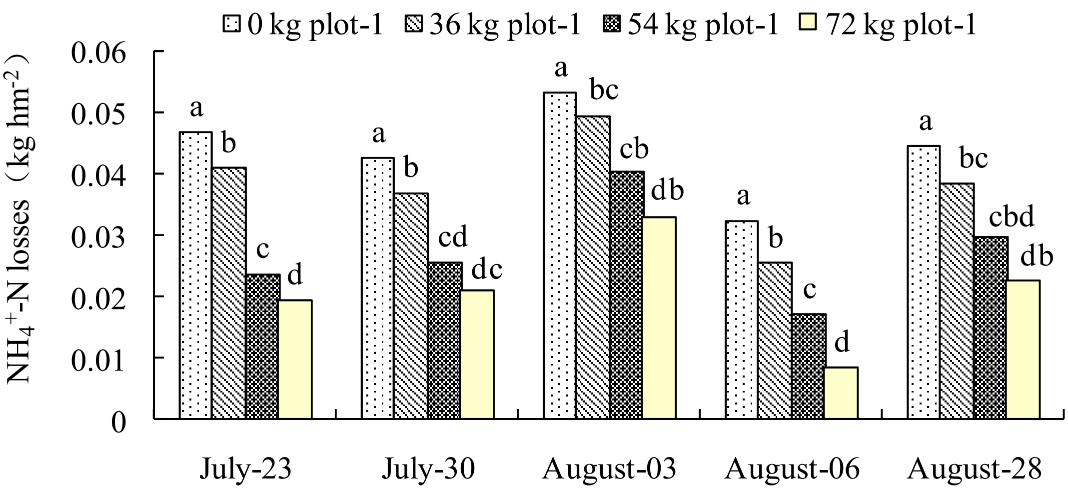


Fig. 2. The effect of straw mulches on loss of CODcr.

3.3 Effects of straw mulching on NH_4^+-N and NO_3^--N losses of surface runoff

The losses of NH_4^+-N with 72 kg plot^{-1} straw mulching with heavy rain were 0.019 kg hm^{-2}, 0.021 kg hm^{-2}, 0.033 kg hm^{-2}, 0.008 kg hm^{-2} and 0.023 kg hm^{-2} at 23 July, 30 July, 3 August, 6 August and 28 August, respectively. Compared with non-treated plots, the total reduction rate of NH_4^+-N with 36 kg plot^{-1}, 54 kg plot^{-1} and 72 kg plot^{-1} straw mulching was 12.56%, 49.38% and 58.60%, respectively (figure 3). The losses of NO_3^--N with 54 kg plot^{-1} straw mulching with heavy rain were 0.049 kg hm^{-2}, 0.051 kg hm^{-2}, 0049 kg hm^{-2}, 0.029 kg hm^{-2} and 0.039 kg hm^{-2} at 23 July, 30 July, 3 August, 6 August and 28 August, respectively. The losses of NO_3^--N with 72 kg plot^{-1} straw mulching with heavy rain were 0.033 kg hm^{-2}, 0.042 kg hm^{-2}, 0.045 kg hm^{-2}, 0.020 kg hm^{-2} and 0.027 kg hm^{-2} at 23 July, 30 July, 3 August, 6 August and 28 August, respectively. Compared with non-treated plots, the total reduction rate of NO_3^--N with 36 kg plot^{-1}, 54 kg plot^{-1} and 72 kg plot^{-1} straw mulching was 27.78%, 39.55% and 58.61%, respectively (figure 3).



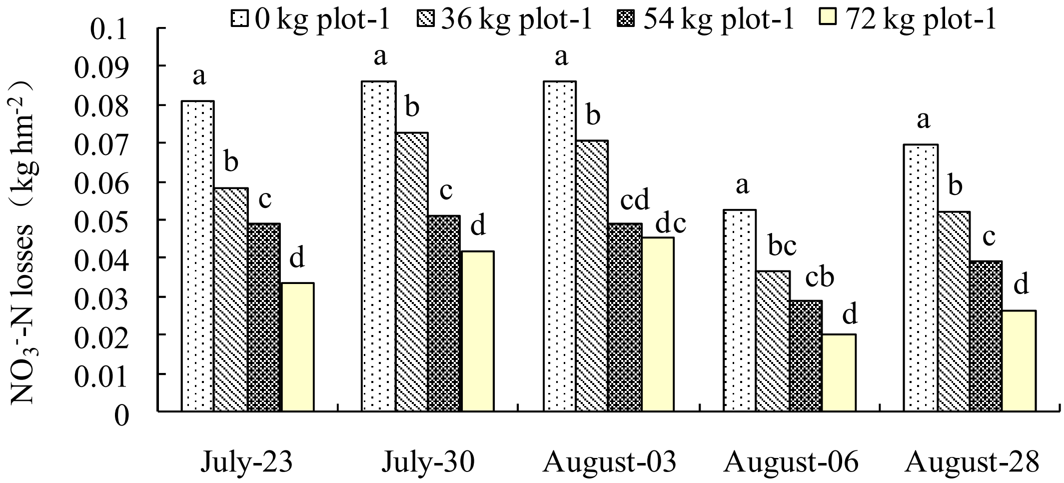


Fig. 3. The effect of straw mulches on the losses of NH_4^+-N and NO_3^--N.

Straw mulching could reduce and intercept surface runoff, which decreased by >30% of NH_4^+-N and NO_3^--N losses, improve N adsorption of crops and fertilizer utilization [13,14]. Rainfall was the main power and carrier of N and P losses [18]. The rain infiltration in soil could be delayed by straw mulching due to water holding capacity of straw. For another thing, the slope runoff flowing rate slowed down with straw mulching and scattered. The loss of NO_3^--N was more than that of NH_4^+-N, which could be relative to the release of NO_3^--N companying with straw rotten [12]. The reduction rate of NO_3^--N occupied >40% of TN losses, which indicated that NO_3^--N was the mainly way of TN loss. NO_3^--N could not be adsorbed by soil colloid and be easy loss with surface runoff [19]. Transfer of NO_3^--N was similar with surface runoff movement, which increased with increase in rainfall [20]. Infiltration depth and amount of soil water and NO_3^--N increased with straw mulching. Some research showed that NO_3^--N content in soil layer 0-200 cm decreased and absorption of plants to NO_3^--N could be enhanced with straw mulching [20]. Other research showed the topsoil water content increased when small rain happened with wheat and maize straw mulching, and subsoil water content increased when median or heavy rain happened [21]. The quantity and activity of soil microbiology increased and resulted in bound-N contents accumulation or N_2 and N_2O volatilization with straw mulching [22,23].

3.4 Effects of straw mulching on TN and TP losses of surface runoff

From May to August with heavy rain, the losses of TN with 54 kg plot^{-1} and 72 kg plot^{-1} straw mulching were 0.080-0.091 kg hm^{-2} and 0.055-0.059 kg hm^{-2}, respectively. Compared with non-treated plots, the total reduction rate of TN with 36 kg plot^{-1}, 54 kg plot^{-1} and 72 kg plot^{-1} straw mulching was 3.85%, 31.67% and 56.01%, respectively (figure 4). From May to August with heavy rain, the losses of TP with 54 kg plot^{-1} and 72 kg plot^{-1} straw mulching were 0.010-0.012 kg hm^{-2} and 0.009-0.010 kg hm^{-2}, respectively. Compared with non-treated plots, the total reduction rate of TP with 36 kg plot^{-1}, 54 kg plot^{-1} and 72 kg plot^{-1} straw mulching was 23.02%, 30.19% and 42.65%, respectively (figure 4). Some researches showed that TN and TP losses decreased by 59.25% and 79.60% with straw mulching, which were due to surface runoff decrease and rain water infiltration increase [12,24]. Infiltration of soil water, N and P to soil increased with increase in straw mulching, resulting in adsorption improvement of N and P of crops. The losses ways of soil P included sediment carrying (particulate P) and runoff carrying (dissolved P). Surface mulching could inhibit effectively soil P losses, especially particulate P losses. Straw mulching increased the surface coverage and decreased washing power of raindrops resulting in relieving in soil runoff. Particulate P losses decreased by from 74%-91% to 64%-79%, and dissolved P losses decreased by 32% with straw mulching (Wang 1986).

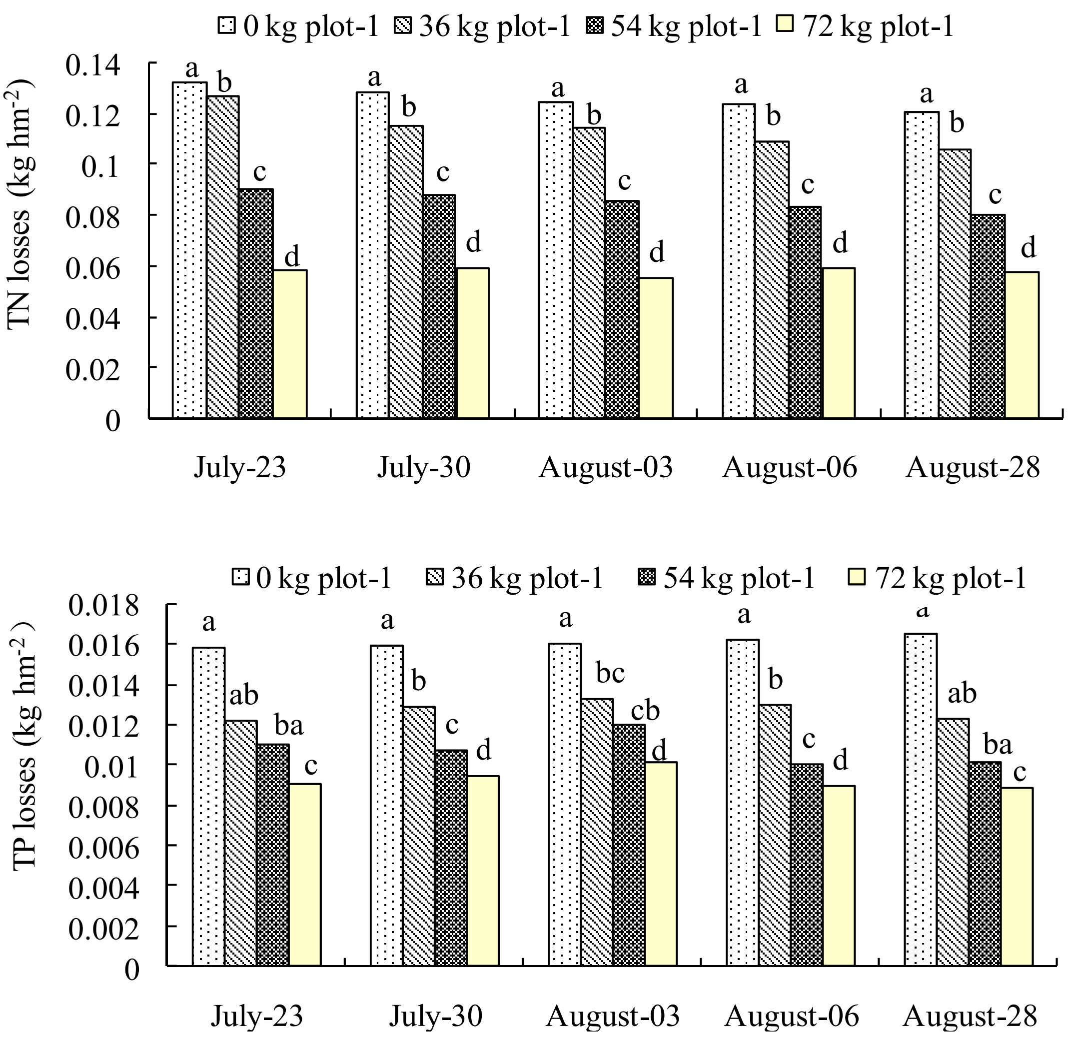


Fig. 4. The effect of straw mulches on the losses of TN and TP.

TN and TP losses of surface runoff decreased with increase in straw mulching rate. To some extent, the reduction rate of TN and TP increased with increase in straw mulching rates, except for mulching rate less than 20%-40% [25]. The relationships between precipitation and losses of NO_3^--N, NH_4^+-N, TN and TP were met to quadratic equation $Y=mX^2+nX+q$ ($m > 0$, $n < 0$, $q > 0$) with straw mulching (table 1). That could be inferred that the N and P contents of surface runoff were the highest level when 43.0 mm d^{-1} precipitation happened. Therefore, N and P losses could be reduced with straw mulching when precipitation less than 43 mm d^{-1}, which occupied 92.5% of local precipitation strength. The coefficient showed $m_1 > m_2 > m_3$ and $n_1 < n_2 < n_3$ in the equations, which indicated that the reduction effect was in sequence 72 kg $plot^{-1}$ > 54 kg $plot^{-1}$ > 36 kg $plot^{-1}$ straw mulching.

Table 1. The relationship between the content of nitrogen and phosphorus and precipitation strength.

Indicator	Treatments (kg $plot^{-1}$)	Equation	R^2	*P*	n
	36	$Y=2.11X^2-7.28X+6.24$	0.822	< 0.05	4
NH_4^+-N	54	$Y=1.77X^2-6.12X+5.19$	0.822	< 0.05	4
	72	$Y=1.21X^2-4.44X+3.94$	0.730	> 0.05	4
	36	$Y=0.17X^2-0.64X+0.82$	0.995	< 0.05	4
NO_3^--N	54	$Y=0.09X^2-0.28X+0.34$	0.999	< 0.05	4
	72	$Y=0.11X^2-0.36X+0.34$	0.998	< 0.05	4

	36	$Y=2.98X^2-10.38X+10.35$	1.000	< 0.05	4
TN	54	$Y=1.76X^2-5.24X+4.52$	0.974	< 0.05	4
	72	$Y=1.19X^2-3.32c+2.78$	0.928	< 0.05	4
	36	$Y=0.55X^2-1.76X+1.68$	0.697	> 0.05	4
TP	54	$Y=0.50X^2-1.70X+1.64$	0.824	< 0.05	4
	72	$Y=0.41X^2-1.35X+1.22$	0.813	< 0.05	4

note：X was precipitation strength (mm h^{-1}). Y was content (mg L^{-1}).

3.5 Effects of straw mulching on soybean yields

Biomass of soybean were 30.00 kg $plot^{-1}$, 40.12 kg $plot^{-1}$, 50.02 kg $plot^{-1}$ and 64.76 kg $plot^{-1}$ with non-treated plots, 36 kg $plot^{-1}$, 54 kg $plot^{-1}$ and 72 kg $plot^{-1}$ straw mulching, respectively. Yield of soybean were 11.04 kg $plot^{-1}$, 13.70 kg $plot^{-1}$, 16.28 kg $plot^{-1}$ and 21.04 kg $plot^{-1}$ with on treated plots, 36 kg $plot^{-1}$, 54 kg $plot^{-1}$ and 72 kg $plot^{-1}$ straw mulching, respectively. Compared with on treated plots, yield of soybean increased by 24.09%, 47.46% and 93.84% with 36 kg $plot^{-1}$, 54 kg $plot^{-1}$ and 72 kg $plot^{-1}$ straw mulching, respectively (Table 2). Yield of soybean increased with straw mulching, which resulted from both soil fertility and crop growth improvement. On the one hand, soil temperature kept stable and soil water and fertilizer use efficiency could be improved with straw mulching during soybean growth stages, which promoted the absorption of crops on soil nutrients [3, 12, 26]. For another thing, number of root nodules, root length and leaf chlorophyll contents of soybean increased, legume full rate increased [27]. Hong et al. (2005) reported the root length increased by 26.6% and depth of root increased 20 cm with straw mulching [28].

Table 2. Effect of straw mulches on biomass and yield of soybean.

Straw mulching	0 kg $plot^{-1}$	36 kg $plot^{-1}$	54 kg $plot^{-1}$	72 kg $plot^{-1}$
Biomass (kg $plot^{-1}$)	30.00	40.12	50.00	64.76
Yield (kg $plot^{-1}$)	11.04	13.70	16.28	21.40

4 Summary and Conclusion

Peach and soybean intercropping system with straw mulching could reduce surface runoff and losses of N, P and COD, increase yield of soybean. The straw mulching rate 600-800 kg mu^{-1} ($667m^2$) in peach and soybean intercropping system could be recommended in Dianchi watershed mountain area, Yunnan Province, China.

Acknowledgements

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