Benefits of precision agriculture application for winter wheat in central China

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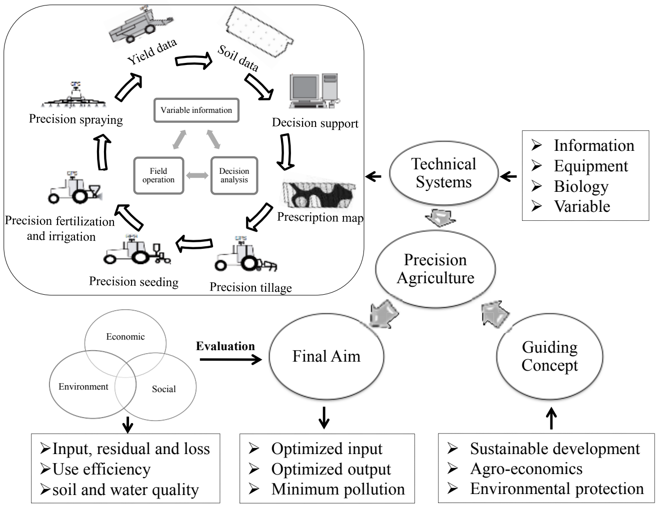
Abstract—**Precision agriculture (PA) has been suggested as a management tool to increase crop performance and improve agricultural environmental quality. In this study, we firstly reviewed the technical systems and bascial benefits of PA, and then evaluated the effects of PA technology on winter wheat yield, residual soil nitrogen and economic benefit.Three treatments, single precision seeding technology (PS), integrated precision seeding with laser land leveling technologies (PLS) and conventional land leveling and seeding technologies (CLS) were established in winter wheat cropland of central China. The result showed that PLS rather than PS significantly increased wheat yield and straw biomass after one season. PS treatment significantly reduced residual soil NO_3^--N and NH_4^+-N, whereas PLS treatment only significantly decreased residual soil NH_4^+-N. Adoption of PA technology increased net return by 4.95%, 37.60% and 30.16% for PS, sudsidy and non-subsidy of PLS treatments, respctively. Our study suggested that integrated PLS was the good application pattern than single PS to improve wheat yield, reduced residual soil nitrogen and increased net return.**

Keywords—precision agriculture; laser land leveling; wheat yield; residual soil nitrogen; economic benefit

I. INTRODUCTION

Grain production was increased by improving crop yield from the decreased cultivated land areas to statisfy the rapidly population growth. Large inputs of nitrogen fertilizer and pesticide in the intensive agriculture has led to eutrophication of natural areas, groundwater [1]. Precision agriculture (PA) was beneficial to crop production and environment coming from more targeted use of inputs due to do the right thing, at the right place, at the right time [2-3]. The guide concept of PA was agricultural sustainable develoment, agroeconomics, resource and environment protection (Fig.1). Variable informations were fully acquired depending on equipment, biology and variable technoloies before decision analysis and field implementation [2]. The basic aims of PA are realization the combination of economic, environment and social benefits (Fig. 1). Evaluations of PA application were separately carried out from the aspects of crop yield and nutrients use efficiency [4-5]. Few studies have simultaneously investigated the economic and environmental benefits of PA.



seeding, fertilization, irrigation, plant protection and harvest (Fig.1). Precision seeding technology reduces the dosage of seed, increases the crop yield and farmer's income [7-8]. However, the seeding quality and crop growth were affected by the uneven fields with dikes and ditches in the conventional leveled fields [6]. It is necessary to integrate the precision seeding with advanced land leveling technology to obtain the higher benefits in agricultural production. Laser-assisted precision land leveling has been reported to enhance survival of young seedlings and stabilize yields through improved nutrient-water interactions [6,9]. However, the benefits of integrated precision seeding with laser land leveling technologies have been few studied so far.

In this study, our objectives were (1) to examine the effects of precision seeding and laser land leveling application on winter wheat crop yield components and residual soil nitrogen; and (2) to distinguish the differences between single precision seeding and integrated precision seeding and laser land leveling.

II. MATERIALS AND METHODS

A. *Site description*

The experiment was conducted at the modern agriculture demonstration district, located in Changge city (113°58'26″E, 34°12'06″N), Henan province in China. The monsoon climate dominates the region with a mean temperature of 17.9 ℃ and a mean annual precipitation of 711.1 mm. The experimental soil (0-20 cm) was a typical medium loam soil with 93.77% sand, 2.66% silt and 3.56% clay. Top soil (0-20 cm) organic matter is 18.40 g/kg, alkali-hydrolyzale nitrogen is 101.22 mg/kg, available phosphorus is 9.83 mg/kg, and soil pH value is 7.65.

B. Experiment design and treatments

The treatment combinations involving two types of land leveling (Local and Laser-assisted) and two seeding practices (Local and precision) were evaluated in the winter wheat during 2014-2015. The experiment design was a randomized block design. Local land leveling combined with local seeding was chosen as the conventional cultivation (CLS). In order to distinguish the benefits of single and integrated PA practices, two treatments were established as follow: (1) local land leveling and precision seeding (PS); (2) laser-assisted land leveling and precision seeding (PLS). The size of the main plots was 300 m×150 m, and divided into three equal replicates.

Land was first ploughed and pulverized at the optimum moisture level with a cultivator, and then leveled and smoothen using a scraper attached to the tractor in the conventional land leveling. A laser-equipped drag scraper with an automatic hydraulic system (1PJ-2500, PAIDE, China) attach to the tractor was used to level the land after ploughing in the laser land leveling treatment. The field was survey at 10 m distance to record the average elevation for leveling before running the laser leveler. The elevation value was entered into the digital control box for controlling the scraper at the desired elevation point [6].

Winter wheat (XN979) was seeded at 20 cm row spacing in 5th October 2014, using a press drill with fertilizer attachment after land leveling in CLS. In PS and PLS treatment, monitoring system and global position system (Wheat seed monitor 100, PAIDE, China) was applied in the conventional seeder to ensure the quantity and linearity of the seeding [10]. The seeding rate in the conventional and precision seeding treatments was 225 kg ha^{-1} and 195 kg/ha, respectively. Wheat was irrigated at tillering stages by flooding about 6 cm above the land surface. Compound fertilizer (N:P:K=23:16:6) was applied in the amount of 725 kg/ha as basal fertilizer, and 225 kg ha^{-1} as tillering fertilizer with the irrigation.

C. Sample collection and measurement

Eighteen sampling point (row×column=3×6) was arranged at 50 m × 50 m spacing using portable GPS in each treatment. Wheat from two randomly selected 1×1 m^2 was cut at 10 cm above ground level surrounding each sampling point. The crops were sun-dried and threshed with a plot to determine grain yield and straw biomass. Grain yield was measured at 13% moisture content and straw biomass was dried to constant weight at 70 °C. Soil samples (0-20 cm) were collected in three subsamples surrounding each sampling point and pooled to one composite sample. Concentrations of nitrate (NO_3^--N) and ammonium(NH_4^+-N) in the fresh soil were extracted with 2 mol L^{-1} KCL and determined by an continuous-flow auto analyzer (Seal AA3, Germany). Total soil carbon (TC) and nitrogen (TN) contents were determined by an element analyzer.

D. Economics analysis

Inputs and prices informations were collected through experimental records and local farmer investigation. All the farming managements were operated by employing socialized service. The cost of total farming captial included agricultural materials input, mechanical service input and labor input. Wheat yield and price was used to calculate the total renturn. Net profits of each tratment was calculated through return subtract cost. Laser land leveling had extra government subsidy in the study area. According to the e-commerce platform Jingdong, Price of compound fertilizer, wheat seed and wheat grain is 0.5 US$/kg, 0.6 US$/kg and 0.4 US$/kg, respectively

E. Statistical analysis

Significant differences among mean values were assessed by one-way ANOVA using least significant difference test. All statistical analyses were conducted using the SPSS software package (version 16.0), and statistical significant differences were set with P values <0.05 unless otherwise stated. All statistical plots were conducted using the SigmaPlot software (version 10.0).

III. RESULTS

A. Wheat yield components soil inorganic N concentration

In the CLS treatment, wheat yield and straw biomass was 7342.94 kg/ha and 9462.34 kg/ha, respectively. PS application did not significantly increase the wheat yield and straw biomass. However, PLS application significantly increased wheat yield and straw biomass by 22.51% and 34.51%, respectively over CLS and by 19.17% and 18.50%, respectively over PS application (Table 1). For wheat spike number, the significant difference was only found between CLS and PLS application (Table 1).

TABLE 1 WINTER WHEAT YIELD COMPONENTS UNDER DIFFERENT EXPERIMENTAL TREATMENTS

Treatment	**Yield (kg/ha)**	**Biomass (kg/ha)**	**Spike number**
CLS	7342.94±707.39 b	9462.34±401.57 b	554±63 b
PS	7549.15±424.22 b	9521.50±1080.00 b	672±61 a
PLS	8 996.02±875.76 a	11283.74±1193.68 a	745±58 a

B. Soil chemical properties

PS and PLS application tended to increase TC and reduce TN, However, the difference was not significant (Fig.1a, Fig.1b). PS rather than PLS application significantly reduced the residual soil NO_3^--N concentration (Fig.1c). Compared with CLS, lower soil NH_4^+-N concentration was simultaneously detected in PS treatment and PLS treatment (Fig.1d).

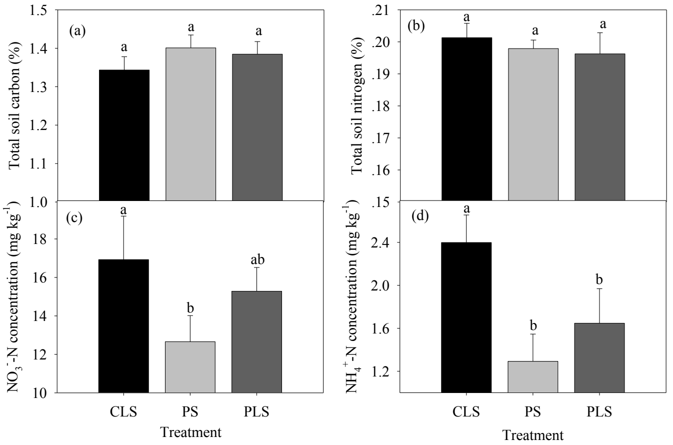


Fig.2. Soil physical and chemical properties under different experimental treatments

C. *Economic benefits analysis*

The conventional cost of CLS, PS and PLS treatments was 1377.3 US$/ha, 1359.3 US$/ha and 1359.3 US$/ha, recptctively. Precision cost of PS treatment was only 23.2 US$/ha, while this value of subsidy and non-subsidy mode of PLS treatment was 92.7 US$/ha and 208.5 US$/ha. Total cost was lower for CLS treatment than PS and PLS treatments, while the contrary results were found in total benefit. The net return was 1559.9 US$/ha for CLS treatments. Adoption of PA increased net return by 4.95%, 37.60% and 30.16% for PS treatment, sudsidy and non-subsidy of PLS treatment, respctively.

TABLE 2 ECONOMIC BENEFITS OF DIFFERENT WHEAT TREATMENTS DURING 2014-2015 (US$/ha).

Economic indicators	**CLS**	**PS**	**PLS**	
			subsidy	**Non-subsidy**
Conventional cost	1377.3	1359.3	1359.3	1359.3
Precision cost	0.0	23.2	92.7	208.5
Total cost	1377.3	1382.5	1452.0	1557.8
Total benefit	2937.12	3019. 7	3598.4	3598.4
Net return	1559.9	1637.2	2146.4	2030.6

IV. DISCUSSIONS

A. *Effects of precision agricultural technology on wheat yield*

Published studies revealed different effects of PA technologies on wheat yield with increases [9,11] or no effects [6]. In our study, we found that single precision seeding application did not show clear effects on wheat yield, whereas integrated precision seeding with laser land leveling application significantly increased wheat yield (Fig.1a). The different responses were attributed to the following two aspects. First, laser land leveling increased water and nutrient-use efficiency [6] and reduced the detriment of soil salinization to wheat booting and grouting [6,11]. Second, laser-assisted precision land leveling enhanced the wheat population density through provided the suitable sowing conditions [12] and improved the survival of young seedlings [6]. In our study, the straw biomass and spike numbers were significantly higher in the PLS treatment than the others (Table 1).

B. *Effects of precision agricultural technology on soil nitrogen residual*

Many studies demonstrated that PA reduced leaching and residual of soil nitrogen through increased N use efficiency [13], despite no effect results have also been documented [14]. In PS treatment, reduced residual soil NO_3^--N and NH_4^+-N concentrations may be attributed to the nitrogen immobilization due to the increased soil TC and reduced soil TN concentration (Fig. 1b), leading to the increased soil C/N ratio. Only reduced residual soil NH_4^+-N concentration was found in PLS treatment (Fig. 1d). The potential reasons include the soil compaction and higher soil pH value. Bai et al. [11] reported that wheel crush of laser-assisted land leveling reduced the water infiltration rate by soil compaction, resulting to the soil NO_3^--N accumulation. Moreover, the promotion of soil mineralization and nitrification by increased soil pH can also contributed to higher soil NO_3^--N contents [15].

C. *Effects of precision agricultural technology on economic benefit*

Our economic benefit results showed that PA application increase net return of winter wheat in central China, especially in PLS tratment (Table 2). This is consisted with the experiment results from rice-wheat rotation system in India [6]. Our results also revealed that intetrated precision agriculture technologies can achieve higher return than single technology application. The increased benefit with precision seeding and laser land leveling was attibuted to increased yield rather than reduced costs of inputs. Irrigated rice systems also demonstrated that the increased profit through reduced fertilizer costs is probably small [4]. In our study, reduced fertilizer and seed costs only saved 16 US$/ha in PS and PLS treatments (Table 2). Although, total cost for PLS was higher than CLS, the benefit from increased wheat yield resulting in higher net return of PLS by 586.53 US$/ha with government subsidy and by 470.43 US$/ha without government subdidy (Table 2).

V. CONCLUSIONS

This study emphasizes the different effects of PS and PLS application on wheat yield, residual soil nitrogen and economic benefits in central China. PS application tended to increase wheat yield, and net return, and significantly reduced residual soil NO_3^--N and NH_4^+-N concentrations, but PLS application significantly increase wheat yield and net return, and only reduced residual soil NH_4^+-N concentration. These results indicated that integrated PLS was the good application pattern than single PS to improve wheat yield, increased net return and reduced residual soil nitrogen.

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