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Consequences of nano nutrients and different fertility levels on productivity of late sown wheat (*Triticum aestivum* L.)

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Abstract
A field experiment was conducted at Instructional Farm of Agronomy, Rajasthan College of Agriculture, Udaipur during rabi season of 2019-20 to find out effect of nano-nutrients and different fertility levels to study their effect on productivity of late sown wheat. The experiment was conducted in clay loam soil which was low in available nitrogen, medium in phosphorus and high in potassium. The results revealed that the application of different fertility levels and spray of nano P, K and Zn at various stages of late sown wheat has significantly influenced the growth and yield characters *viz*., plant height and dry matter, effective tillers, number of grains ear^{-1}, test weight, grain, straw and biological yield etc. and also increased nutrient concentration of plant and soil sample. The maximum plant height (114.86 cm), maximum dry matter accumulation (50.09 g plant^{-1}) at 45 DAS and (224.07 g plant^{-1}) at harvest, chlorophyll content of flag leaf was 2.417 mg g^{-1} of fresh leave weight was recorded with the treatment application of T7, which was not differing significantly with the treatments T8 and T10. The maximum number of effective tillers meter^{-1} row length (82.05), number of grains ear^{-1} (41.70), test weight (55.84 g) and yield of wheat crop grain (4832.5 kg ha^{-1}), straw (6958.3 kg ha^{-1}) and biological yield (11790.8 kg ha^{-1}) under the treatment application of T7, which statistically at par with T8, T9 and T10. The highest gross and net return 113901 and 84193 ` ha^{-1} respectively and benefit cost ratio of 2.83 was gained under the application of treatment T7, which was statistically at par with the treatment T10.

Keywords: nano nutrients, fertility levels, productivity, late sown wheat

Introduction
Wheat (*Triticum aestivum*) is one of the most important staple food crops of the world, occupying 17 per cent (one sixth) of crop acreage worldwide, feeding about 40 per cent (nearly half) of the world population and provide 20 per cent (one fifth) of the total food calories and protein in human nutrition. There are different species of wheat out of which only three *Triticum* species are mostly cultivated throughout the world.

Globally, wheat (*Triticum spp*.) is grown in an area of approximately 220 mha holding the highest acreage position among all crops, with annual production of around 781 mt. In India, it is grown in an area of 29.55 m ha (13.43% of global area) with a production of 101.20 mt (12.96% of world production) and productivity of 3424 kg ha^{-1}. In Rajasthan, it is grown in an area of 2.88 m ha with a production and productivity of 9.60 mt and 3334 kg ha^{-1}, respectively. In Rajasthan wheat is grown mainly in the districts of Sri Ganganagar, Hanumangarh, Alwar, Bharatpur, Churu, Jaipur, Kota, Baran, Bundi *etc.*

Nanotechnology is an emerging utensil to advance efficiency of crop production and has ability to coup-up from present agricultural problems. The term "Nanotechnology" originated in a Greek word 'nanos' meaning "dwarf". Because of the shortage of arable land, limited water and nutrient resources, the development of agriculture sector is only possible by increasing resource use efficiency with the minimum damage to production bed through effective use of modern technologies (Joshi *et al*., 2019; Naderi and Shahraki, 2013) [9, 13].

Nanotechnology holds promise and nano-fertilizers can go a long way in ensuring sustainable soil health and crop production (Lal, 2008). Nanotechnology occupies a prominent role in transforming agriculture and food production. Nanotechnologies are already revolutionized the healthcare, textile industry, information and communication technology and energy sectors but its supplications are still at infancy stage in agriculture.

Nano-fertilizers are designed in order to gradually release their food contents. They are also manufactured in such a way that the time of their liberation matches with the food product requirement. They contain ferrous, silica, titanium dioxide, nano zinc, core shell gold nanorods etc., in addition to should sanction control release and improve its quality. The use of nano-fertilizers leads to an increase in the efficiency of the consumption of food elements. Phosphorus is the second most important element for plants after nitrogen and it is essential for cell division, cell enlargement, energy storage and transfer, enhancing seed maturity and seed development (Ziadi *et al*., 2008) [16], improved photosynthetic activity and transport to the ripening grains. This resulted weightier grains. N and P uptake could be enhanced with increased phosphorus applications. Potassium is having one of special significance because of its active role in bio-chemical functions of plant *e.g.* activating various enzymes, protein formation, carbohydrates and fat concentration, tolerance to drought and resistance to frost, lodging, pests and disease attack. Zinc is needed for the production of chlorophyll, pollen, fertilisation and germination. Zinc plays important role in biomass production (Kaya and Higgs, 2002). Keeping in view of the growing importance in the application of nano materials in agriculture, during the *rabi* 2019-20 the current investigation was laid out during rabi season of 2019-20 to find out effect of nano-nutrients and different fertility levels to study their effect on productivity of late sown wheat.

Methodology

The experiment was implemented at the Agronomy Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur, situated at an altitude of 582.17 meters above sea level with 24°35' N latitude and 73°42' E longitude in the south-eastern part of Rajasthan. The area lies under the Rajasthan's agro-climatic zone IVa (Sub-Humid Southern Plain and Aravalli Hills). This zone has typical subtropical climatic conditions characterized by pleasant winters and moderate summer associated with high relative humidity during the months of July to September. The mean annual rainfall of this region is 600 mm, most of which is contributed by south-west monsoon from July to September. Rainfall received during crop season was 4.20 mm. The mean weekly meteorological parameters recoded at Agro-meteorological observatory, Rajasthan College of Agriculture, Udaipur during cropping period are presented in Table 3.1 and Fig. 3.1. The maximum and minimum temperature ranges between 33.0°C to 21.0°C and 14.5°C to 4.4°C, respectively. The minimum and maximum relative humidity ranges between 88.0 to 54.7 and 49.3 to 21.9 per cent, respectively. The total rainfall and maximum evaporation were 5.6 and 7.1 mm was recorded.

Physico-chemical properties of experimental soil

In order to determine the physic-chemical characteristics of the soil, samples were collected randomly from the investigation site up to a penetration of 15 cm and a composite sample was prepared. A representative soil sample for the different physical and chemical properties of the experimental soil was analysed. Table 3.2 presents the results of the soil analysis before sowing of crop, along with the methods used for the above-mentioned determinants. The soil texture of the experimental site is clay loam, slightly alkaline in reaction, low in available nitrogen, medium in available phosphorus and high in available potassium. The experiment was laid out in Randomized Block Design comprising eleven treatments *viz.*, T1[100 per cent RDF], T2[100 per cent RDF + spray of nano P after first irrigation], T3[100 per cent RDF + spray of nano K after first irrigation], T4[100 per cent RDF + spray of nano Zn after first irrigation], T5[100 per cent RDF + 1st spray of nano P after first irrigation + 2nd spray of nano P after 15 days of the first spray], T6[100 per cent RDF + 1st spray of nano K after first irrigation + 2nd spray of nano K after 15 days of the first spray], T7[100 per cent RDF + 1st spray of nano Zn after first irrigation + 2nd spray of nano Zn after 15 days of the first spray], T8[75 per cent RD of P (100% N, K) + 1st spray of nano P after first irrigation + 2nd spray of nano P after 15 days of the first spray], T9[75 per cent RD of K (100% N, P) + 1st spray of nano K after first irrigation + 2nd spray of nano K after 15 days of the first spray], T10[75 per cent RD of Zn (100% N, P & K) + 1st spray of nano Zn after first irrigation + 2nd spray of nano Zn after 15 days of the first spray] and T11[50 per cent RDF + 1st spray of nano P after first irrigation followed by K (15 days after P spray), followed by Zn (15 days after K spray)] with three number of replications having total 33 plots. Treatments were applied as per the treatment recommendation. For RDFs P was supplied through DAP, nitrogen by subtracting the amount of N supplied through DAP and remaining by urea and K through MOP. Full dose of P and K and half of N was applied at the basal and remaining N was supplied in two equal splits during 1st and 2nd irrigation. Nano P, K and Zn was sprayed according to the treatments and time at the rate of 10 per cent solution. In direction to study of growth, yield attributing characters and yield of crop, observations were recorded for each parameter as per method mentioned below.

Growth attributes

Plant height

Plant height was recorded at 45 DAS and at harvest on the basis of five randomly selected plants. From each plot the plant height was measured from the base of the plant to fully opened uppermost leaf tip with the help of metre scale and the average plant height was worked out and expressed in centimetre.

Dry matter accumulation

The periodic changes in dry matter accumulation plant^{-1} was recorded at 45 DAS and at harvest by uprooting randomly selected five plants from each plot. These samples were placed in punctured paper begs followed by sun drying for at least two days and then kept in oven at 65°C for 48 to 72 hours till a constant dry weight perceived. Dry matter accumulation plant^{-1} was computed for each treatment at respective stages and expressed as g plant^{-1}.

Yield and yield attributes

Number of effective tillers meter^{-1} row length

Number of effective tillers meter^{-1} row length were counted a from randomly selected five rows from one-meter row length and averaged.

Number of grains ear^{-1}

Spikes collected randomly from five plants were threshed, cleaned and total number of grains were counted and the average number of grains ear^{-1} were recorded.

Test weight

1000 grains were counted in sample drawn from the finally winnowed and cleaned produce of each plot after weighing. These counted grains were weighed on electronic balance and the weight was recorded in gram.

Yield

After threshing and winnowing grain yield of net plot was recorded and used to compute seed, straw and biological yield as kg ha^{-1}.

Harvest index

It is the ratio of economic yield (grain yield) to biological yield, and worked out by following formula (Donald and Hamblin, 1976) [7] expressed in percentage.

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}} \text{x}100$$

Economics analysis

Treatment economics is the prime factor before making suggestions to farmers for adoption. Therefore, rigorous economics including net returns (` ha^{-1}) and BC ratio was calculated to evaluate treatment efficacy and productivity so that the most feasible and remunerative treatment could be recommended. Calculation information with prevailing input and output market rates are given at the end in the annexes.

Results and Discussion

Effect of nano nutrients and different fertility levels on growth parameters

A statistical analysis of the data presented in Table 1 shows that at 45 DAS of late sown wheat crop nano-nutrients and fertility rates did not show any significant effect on plant height. However, the significant effect of nano-nutrients and fertility levels has recorded on plant height at harvest. The maximum plant height (114.86 cm), maximum dry matter accumulation (50.09 g plant^{-1}) at 45 DAS and (224.07 g plant^{-1}) at harvest, chlorophyll content of flag leaf was 2.417 mg g^{-1} of fresh leave weight was recorded with the treatment application of T7 [100 per cent RDF + 1st Spray of nano Zn after first irrigation + 2nd spray of nano Zn after 15 days of the first spray], which was not differing significantly with the treatments T8 [75 per cent RD of P (100% N, K) + 1st Spray of nano P after first irrigation + 2nd spray of nano P after 15 days of the first spray] and T10 [75 per cent RD of Zn (100% N, P & K) + 1st Spray of nano Zn after first irrigation + 2nd spray of nano Zn after 15 days of the first spray].

The most significant function of N in the plant is its presence in the protein structure, where the living material or protoplasm of all cells is produced. Nitrogen is also present in the green colouring matter of the leaves, chlorophyll. Chlorophyll allows the plant to photosynthesize energy from sunlight. The amount of protein, protoplasm and chlorophyll formed will therefore be affected by the supply of nitrogen to the plant. It in turn affects cell size and the area of the leaf and photosynthesis. Phosphorus is an essential nutrient both as part of many significant compounds of the plant structure and as a catalyst in the conversion of various major biochemical plant reactions. Phosphorus is best known for its role in the capture and transformation of sun energy into useful plant compounds. Phosphorus is a main component of ATP, the plant energy complex. During photosynthesis ATP absorbs phosphorus in its structure and processes from the start of seedling growth to grain formation and maturity. Phosphorus is therefore important to the overall health and vigour of all plants. Potassium is related to the movement of plant tissue water, nutrients and carbohydrates. It involves the activation of enzymes within the plant which affects the production of protein, starch and adenosine triphosphate (ATP). The ATP production will change the photosynthesis rate. Potassium also helps the regulation of the stomach opening and closing, which controls water vapor and oxygen exchange and carbon dioxide. If K is insufficient or inadequately supplied, it slows down plant growth and decreases yield. The plant height and dry matter increased linearly with each successive increase in NPK which was attributed to the gradual increase in plant height. These results are in agreement with findings of Ayub *et al.* (2002) [5]; Maqsood *et al.* (2001); Hiyasmin *et al.* (2015) [8] and Al-Juthery *et al.* (2018) [4].

The increase in plant height, dry matter and total chlorophyll of leaves by spraying of nano-P, K and Zn fertilizers and RDFs are attributed to the role of these nutrients in stimulating plant growth. These nutrients are required for healthy and ideal growth of the plant to complete its life cycle (Ali, 2012) [3]. It plays a role in many of its physiological functions in plant growth and development. These functions include the synthesis of chlorophyll and thylakoid and the development of chloroplasts (Masoud *et al.*, 2012). It also plays a role in the transfer of energy within the plant and in many enzymatic activities and photosynthesis as well as respiration and synthesis of proteins, therefore, has a key role in plant growth (Ali, 2012; Yaseen *et al.*, 2011) [3, 15].

2 Effect of nano nutrients and different fertility levels on yield attributing characteristics and yield

The results of data (Table 2) revealed that the nano-nutrient spray and fertility had shown significant effect on yield attributing characteristics *viz.*, number of effective tillers meter^{-1} row length, number of grains ear^{-1}, test weight and yield *i.e.* grain, straw and biological yield of wheat crop. The maximum number of effective tillers meter^{-1} row length (82.05), number of grains ear^{-1} (41.70), test weight (55.84 g) and yield of wheat crop grain (4832.5 kg ha^{-1}), straw (6958.3 kg ha^{-1}) and biological yield (11790.8 kg ha^{-1}) under the treatment application of T7[100 per cent RDF + 1st Spray of nano Zn after first irrigation + 2nd spray of nano Zn after 15 days of the first spray], which was statistically at par with the treatments T8 [75 per cent RD of P (100% N, K) + 1st spray of nano P after first irrigation + 2nd spray of nano P after 15 days of the first spray], T9 [75 per cent RD of K (100% N, P) + 1st spray of nano K after first irrigation + 2nd spray of nano K after 15 days of the first spray] and T10 [75 per cent RD of Zn (100% N, P & K) + 1st spray of nano Zn after first irrigation + 2nd spray of nano Zn after 15 days of the first spray] under most of observation.

It has been suggested that improvement of the grain yield under nano nutrients spray treatments might be associated with the enhanced chlorophyll content, number of effective tillers, number of grains ear^{-1}, test weight and hereby improving the performance of the plants under suboptimal growth conditions. A positive and significant correlation between grain yield and plant height at harvest (r=0.862**), Dry matter accumulation at harvest (r=0.884**), effective tillers meter^{-1} row (r=0.722*), number of grain ear^{-1} (r=0.859**) (Table 5.1). Nano micronutrient foliar application (P, K and Zn) can play a critical role in the crop production, involving photosynthesis processes and thus other biochemical and physiological triggers their value in generating higher yield and yield attributes. The increasing levels of RDFs increase the wheat yield up to a certain extent. This might be due to the interaction effect of nitrogen with phosphorus and potassium (Maqsood *et al.*, 2001), who concluded that grain yield of cereal crops increased with application of NPK fertilizer. The use of essential nutrients on the leaves will increase the synthesized production of metabolites and the plant thus had the opportunity to provide more fertile tillers metre^{-2} (Abdallah and Hanaa, 2013) [1]. Zinc application plays a vital role in the processing of dry matter and grain yield into cereals through diverse physiological and biochemical processes.

Nanoparticles act as a powerful photocatalyst by improving the photosynthetic activity and complexes and the metabolism of nitrogen, which can improve cell production, and the fresh and dry weight of treated plants. Phytohormones, particularly cytokinines, were assumed to play an important role in increasing sink size by promoting cell separation during the early seed filling process. More recently, however, research has shown that grain mass and the number of endosperm cells in wheat are closely related. The number of grains per spike is generally known by assimilates and is limited by the availability of post-phloemic assimilates (Saalbach *et al.*, 2014) [14]. These results are closely in line with the findings of Afshar *et al.* (2014) [2]; Dapkekar *et al.* (2018) [6] and Al-juthery *et al.* (2019) [4].

Table 1: Effect of nano nutrients and different fertility on plant height, dry matter and chlorophyll content

Treatment		Plant height (cm)		Dry matter (g)		Chlorophyll content in flag leaf (mg/g of fresh leaf)
		45 DAS	At harvest	45 DAS	Harvest	
T1:	100% RDF	41.45	85.78	37.43	215.92	1.941
T2:	100% RDF + Spray of nano P after first irrigation	46.43	100.55	41.07	217.87	2.063
T3:	100% RDF + Spray of nano K after first irrigation	43.51	91.60	41.95	218.68	2.088
T4:	100% RDF + Spray of nano Zn after first irrigation	47.59	99.41	42.59	219.26	2.005
T5:	100% RDF + 1st Spray of nano P after first irrigation + 2nd spray of nano P after 15 days of the first spray	43.87	92.44	42.88	219.53	2.050
T6:	100% RDF + 1st Spray of nano K after first irrigation + 2nd spray of nano K after 15 days of the first spray	42.86	96.21	44.04	220.58	2.079
T7:	100% RDF + 1st Spray of nano Zn after first irrigation + 2nd spray of nano Zn after 15 days of the first spray	50.82	114.86	50.09	224.07	2.417
T8:	75% RD of P (100% N, K) + 1st Spray of nano P after first irrigation + 2nd spray of nano P after 15 days of the first spray	44.95	95.96	46.86	223.10	2.167
T9:	75% RD of K (100% N, P) + 1st Spray of nano K after first irrigation + 2nd spray of nano K after 15 days of the first spray	51.33	110.69	42.98	220.67	2.079
T10:	75% RD of Zn (100% N, P & K) + 1st Spray of nano Zn after first irrigation + 2nd spray of nano Zn after 15 days of the first spray	47.68	102.39	46.04	223.10	2.400
T11:	50% RDF + 1st Spray of nano P after first irrigation followed by K (15 days after P spray), followed by Zn (15 days after K spray)	47.91	84.27	47.48	214.95	1.913
SEm±		2.11	5.28	2.27	0.36	0.104
CD (p=0.05)		NS	15.58	6.70	1.05	0.307

Table 2: Effect of nano nutrients and different fertility on yield attributing characters of wheat crop

Treatment		Number of effective tillers meter^{-1} row length	Number of grain ear^{-1}	Test weight (g)
T1:	100% RDF	66.60	32.13	41.81
T2:	100% RDF + Spray of nano P after first irrigation	76.85	36.93	49.24
T3:	100% RDF + Spray of nano K after first irrigation	66.60	36.21	47.47
T4:	100% RDF + Spray of nano Zn after first irrigation	76.85	36.30	46.56
T5:	100% RDF + 1st Spray of nano P after first irrigation + 2nd spray of nano P after 15 days of the first spray	81.62	36.79	49.42
T6:	100% RDF + 1st Spray of nano K after first irrigation + 2nd spray of nano K after 15 days of the first spray	81.62	36.75	46.65
T7:	100% RDF + 1st Spray of nano Zn after first irrigation + 2nd spray of nano Zn after 15 days of the first spray	82.05	41.70	55.84
T8:	75% RD of P (100% N, K) + 1st Spray of nano P after first irrigation + 2nd spray of nano P after 15 days of the first spray	76.85	36.33	47.97
T9:	75% RD of K (100% N, P) + 1st Spray of nano K after first irrigation + 2nd spray of nano K after 15 days of the first spray	81.62	37.96	46.98
T10:	75% RD of Zn (100% N, P & K) + 1st Spray of nano Zn after first irrigation + 2nd spray of nano Zn after 15 days of the first spray	81.62	39.65	47.85
T11:	50% RDF + 1st Spray of nano P after first irrigation followed by K (15 days after P spray), followed by Zn (15 days after K spray)	66.60	34.31	47.26
SEm±		4.27	1.57	2.05
CD (p=0.05)		12.59	4.63	6.05

Table 3: Effect of nano nutrients and different fertility on yield of wheat crop

Treatment		Yield (kg ha^{-1}) Grain	Straw	Biological	Harvest index (%)
T1:	100% RDF	3620.5	5202.6	8823.2	41.02
T2:	100% RDF + Spray of nano P after first irrigation	3755.6	5401.0	9156.7	41.01
T3:	100% RDF + Spray of nano K after first irrigation	3835.5	5519.3	9354.7	41.01
T4:	100% RDF + Spray of nano Zn after first irrigation	3862.5	5559.3	9421.8	41.01
T5:	100% RDF + 1^{st} Spray of nano P after first irrigation + 2^{nd} spray of nano P after 15 days of the first spray	3944.9	5681.1	9626.0	41.01
T6:	100% RDF + 1^{st} Spray of nano K after first irrigation + 2^{nd} spray of nano K after 15 days of the first spray	3972.8	5722.3	9695.1	41.01
T7:	100% RDF + 1^{st} Spray of nano Zn after first irrigation + 2^{nd} spray of nano Zn after 15 days of the first spray	4832.5	6958.3	11790.8	41.05
T8:	75% RD of P (100% N, K) + 1^{st} Spray of nano P after first irrigation + 2^{nd} spray of nano P after 15 days of the first spray	4233.6	6105.8	10339.4	41.01
T9:	75% RD of K (100% N, P) + 1^{st} Spray of nano K after first irrigation + 2^{nd} spray of nano K after 15 days of the first spray	4672.0	6733.1	11405.0	41.03
T10:	75% RD of Zn (100% N, P & K) + 1^{st} Spray of nano Zn after first irrigation + 2^{nd} spray of nano Zn after 15 days of the first spray	4745.2	6827.6	11572.8	41.05
T11:	50% RDF + 1^{st} Spray of nano P after first irrigation followed by K (15 days after P spray), followed by Zn (15 days after K spray)	3474.4	5024.9	8499.2	41.05
SEm±		219.6	279.0	498.2	0.15
CD (p=0.05)		647.8	822.9	1469.6	NS

Table 4: Effect of nano nutrients and different fertility on economics of wheat

Treatment		Return (` ha^{-1}) Gross	Net	BC ratio
T1:	100% RDF	85303.35	48395.75	1.31
T2:	100% RDF + Spray of nano P after first irrigation	88499.16	51111.56	1.37
T3:	100% RDF + Spray of nano K after first irrigation	90390.71	60203.11	1.99
T4:	100% RDF + Spray of nano Zn after first irrigation	91031.26	53643.66	1.43
T5:	100% RDF + 1^{st} Spray of nano P after first irrigation + 2^{nd} spray of nano P after 15 days of the first spray	92982.74	56075.14	1.52
T6:	100% RDF + 1^{st} Spray of nano K after first irrigation + 2^{nd} spray of nano K after 15 days of the first spray	93643.36	56735.76	1.54
T7:	100% RDF + 1^{st} Spray of nano Zn after first irrigation + 2^{nd} spray of nano Zn after 15 days of the first spray	113901.10	84193.50	2.83
T8:	75% RD of P (100% N, K) + 1^{st} Spray of nano P after first irrigation + 2^{nd} spray of nano P after 15 days of the first spray	99814.11	63325.26	1.74
T9:	75% RD of K (100% N, P) + 1^{st} Spray of nano K after first irrigation + 2^{nd} spray of nano K after 15 days of the first spray	110134.46	73471.86	2.00
T10:	75% RD of Zn (100% N, P & K) + 1^{st} Spray of nano Zn after first irrigation + 2^{nd} spray of nano Zn after 15 days of the first spray	111827.17	82482.07	2.81
T11:	50% RDF + 1^{st} Spray of nano P after first irrigation followed by K (15 days after P spray), followed by Zn (15 days after K spray)	81955.94	35689.64	0.77
SEm±		5061.78	5061.78	0.15
CD (p=0.05)		14932.25	14932.25	0.45

Conclusion

On the basis of results emanated from the present investigation conducted during *rabi 2019-20* it is concluded that under the prevailing agroclimatic conditions, late sown wheat crop fertilized with 100 per cent RDF + 1^{st} Spray of nano Zn after first irrigation + 2^{nd} spray of nano Zn after 15 days of the first spray has proved most efficient in enhancing yield of late sown wheat crop and also found economically viable treatment. However, this treatment has produced seed yield 4832.5 kg ha^{-1}, straw yield 6958.3 kg ha^{-1}, biological yield 11790.8 kg ha^{-1}, gross return ` 113901 ha$^{-1}$, net return ` 84193 ha^{-1} and BC ratio of 2.83.

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