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Effect of plasma and nanotechnology on nutrient use efficiency of wheat (*Triticum aestivum* L.)

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Abstract
A field experiment entitled “effect of Plasma and Nanochitosan on NPK content and use efficiency of Wheat *(Triticum aestivum* L.)” was conducted at N.E. Borlaug crop research centre, Pantnagar during *rabi* 2017-18. The treatments comprised of combination of four fertilizer levels in main plot and three seed treatment levels (control, plasma and nanochitosan@50 ppm) in subplot laid out in split plot design with three replications. Among all treatments full dose of fertilizer (150:60:40 Kg/ha) along with nanochitosan recorded higher use efficiency which was at par with 3/4th dose of fertilizer plus plasma. Hence, plasma and nanotechnology found promising for improving nutrient use efficiency (NUE) of Wheat.

Keywords: Nutrient use efficiency, eco-friendly, profitable

Introduction
Modern farms and agricultural operations work far differently than those a few decades ago, primarily because of advancements in technology, including sensors, devices, machines, and information technology. Today’s agriculture routinely uses sophisticated technologies such as robots, temperature and moisture sensors, aerial images, and GPS technology. These advanced technologies allow agriculture to be more profitable, efficient, safer, and more environmentally friendly. The rapid increase in global population, the demand of food grain and agricultural yield has been rising tremendously. Due to enforce to grow more food indiscriminate use of fertilizer occurs which may cause imbalance of nutrients in soil, make hazardous to environment and increase cost of production. Therefore, agricultural productivity has been stagnated (Bokhtiar, *et al.*, 2005) [3] and we need to develop a new technology to increase crop production without harming cost and environment (Hazra, *et al.*, 2016) [8]. The basic aim of these developing technologies are research and development in physical sciences, engineering, and computer sciences related to agriculture development of agricultural devices, sensors, and applied research that assesses how to employ technologies economically in addition with minimal disruption to existing practices as well as assistance and instruction to farmers on how to use new technologies.

New technologies such as plasma and nanotechnology are making promise and proved their use in different sectors of society but limited studies were done in agriculture. Plasma denominate substance with a high, unstable energy level that have more or less equal number of positive and negative charged particle or reactive species, created when gas become ionized (Fig 1). When plasma comes into contact with solid materials, the surfaces get excited and change their important properties, such as the surface energy, rate of imbibition etc., which helps to accelerate physiological processes of plants together with surface etching effect resulted increase permeability towards seed coat, surface modification of seed coat, stimulate seed germination and seedling growth of the plant. It also increases the physiological metabolism of plant such as superoxide dismutase and peroxidase activities, photosynthetic pigments, photosynthetic efficiency and nitrate reductase activity. Such morphological modifications on seed surfaces are safe and inconceivable to have any genetic impact. Therefore, plasma technology may consider as a fast, economic and pollution-free method to improve crop production (Dobrin *et al.*, 2015) [6].

Nanotechnology has proved their worth in agriculture. This is a powerful technology which can have ability to create massive changes in food and agriculture system. Nanofertilizers release the nutrients as on requirement of crop and preventing them from prematurely interaction with soil, water environment and microorganisms and release nutrient directly assemble into the plant system effectively. These unique characteristics can improve nutrient use efficiency of crop (DeRosa *et al.*, 2010) [5]. Chitosan nanoparticles have good association and loading efficiency values of a model substance which is showing their ability as a nano carrier for nutrient delivery systems and also act as a slow release fertilizers that are only little bit soluble in water or are slowly broken down by microbial action (Prasad *et al.*, 2009) [11]. Thus, the rate of nutrient liberation from slow release fertilizers is related to their water solubility, microbiological degradation, and chemical hydrolysis and NO_3 --N leaching is decreased by applying slow release fertilizers coated with nano-materials.

Now a days seed treatment seems to be more popular because it improves germination rates, revamp ease of handling and accuracy of planting and indemnity of cost reduction of seed treatment. Germination and seedling stages are crucial for healthy plant growth. The presence of biotic (diseases) and abiotic stresses (temperature and salt) at these stages can influence the successful establishment of crop. Plasma and Nanotechnology of seeds is come forth platforms to apostrophize these issues. Plasma seed treatments bestow to seed germination enhancement and rises plant productivity. Nanochitosan are easily applied to seed's surface and enter the nano pores of cell wall and cell membrane of the seed, by avoiding direct interaction with soil systems and increases harvest index, crop index and mobilization index of yield factors, as compared with factor treated with normal non-fertilized and normal fertilized (Aziz *et al.*, 2016) [1].

Materials and methods

A field experiment was conducted at N.E. Borlaug crop research centre, pantnagar during *rabi* 2017-18. Plasma seed treatment was done at institute of plasma research, bhat, gandhinagar (Gujarat) but purchased nanochitosan treatment was carried out at nanotechnology lab of pantnagar under aseptic conditions. This experiment was laid out in split plot design having 3 replications and 12 treatment combinations (full dose of fertilizer+ control, full dose of fertilizer+ nanochitosan, full dose of fertilizer+ plasma, 3/4th dose of fertilizer+ control, 3/4th dose of fertilizer+ nanochitosan, 3/4th dose of fertilizer+ plasma, ½ dose of fertilizer+ control, ½ dose of fertilizer+ nanochitosan, ½ dose of fertilizer+ plasma, no fertilizer+ control, no fertilizer+ nanochitosan+ nanochitosan and no fertilizer+ plasma). In main plot four levels of fertilizer doses full dose of RDF (Recommended dose of fertilizer; 150:60:40 N:P:K Kg/ha), 3/4th dose of fertilizer, ½ dose of fertilizer and no fertilizer but in subplot, three seed treatment methods, control, plasma treatment at 6 minute and nanochitosan at 50 ppm concentration occurs. HD- 2967 variety of wheat was used for experimental purpose and several observations such as nitrogen, phosphorus and potassium content and their uptake, agronomical efficiency, partial factor productivity, nutrient harvest index was recorded. Agronomic practices, 1-2 primary tillage, 2-3 harrowing and one leveling was performed prior to sowing while no herbicide use for weed control only 2 hand-weeding. Check basin method was used for irrigation and irrigation was given at all the critical stages (crown root initiation, tillering, jointing, flowering, milking and dough stage).

Plasma seed treatment

The wheat seeds were treated in a capacitively coupled plasma reactor consists of Stainless Steel (SS) chamber with rotary pump for creating necessary sub-atmospheric vacuum (Fig. 1& 2). The plasma treatment of wheat seeds was done using air plasma formed radio frequency supply (13.56 MHz) with treatment time 2, 4, 6, 8 and 15 minutes with fixed 50 watts coupled power and 0.7 mbar pressure. This treatment was done at institute of plasma research, Ahmedabad.

Nanochitosan seed treatment

Nanochitosan purchased from nanoshell, Wilmington (USA), 50ppm of it used for experiment purpose that have $C_6H_{11}NO_4$ (Molecular formula), > 99% Purity, 1.4 Specific gravity, Cost price 1000 Rs/gram and White Appearance. For preparing 50 ppm nanochitosan solution weighed the nanochitosan at 0.050 gram or 50 mg and blended in 1 liter distilled water with the help of magnetic stirrer for 30 minutes, for equal distribution of it into the distilled water. The seeds of wheat were immersed in a sodium hypochloride solution for 2 minutes for surface sterilization of seeds then they were soaked in nanochitosan 50 ppm solution for 3 hours. Treated seeds were shade dry over muslin cloth for 24 hours. This process was done one day before the sowing of wheat seeds.

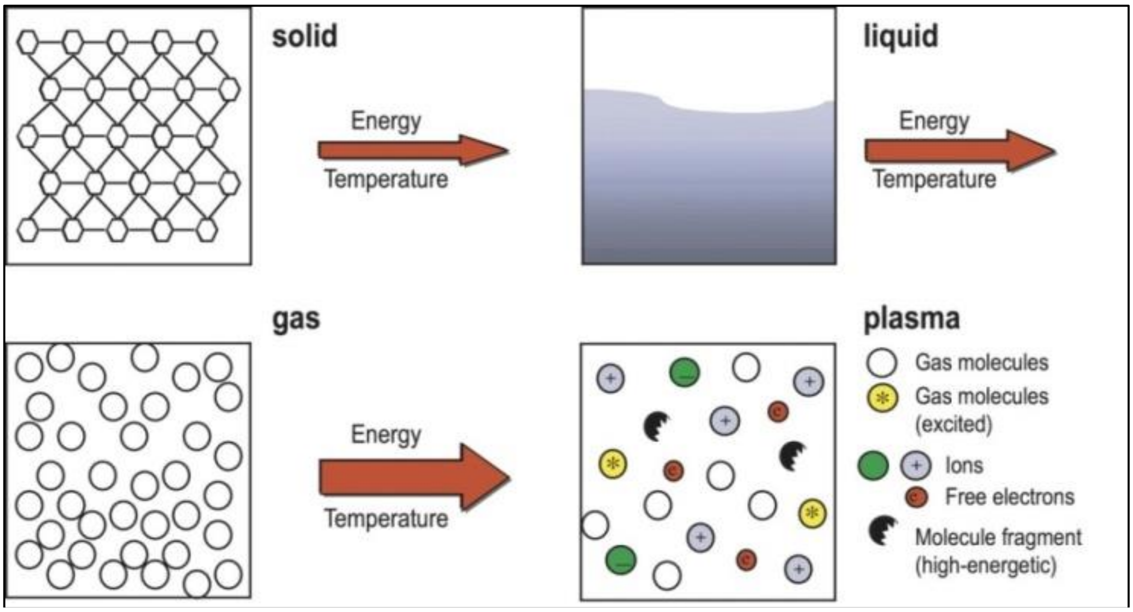

Fig 1: Formation of active molecules (plasma)

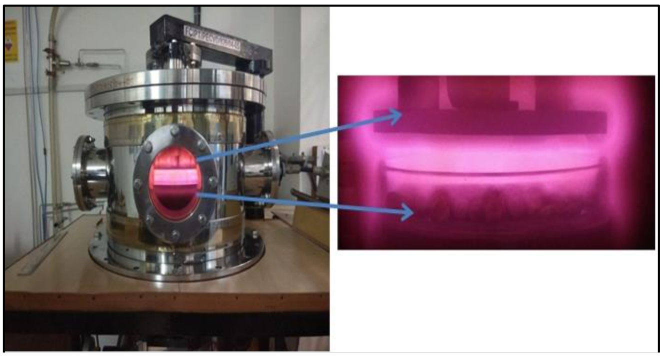

Fig 2: Radio frequency plasma system for wheat seed treatment (in-set shows closer view of plasma)

Plant nutrient analysis

Composite bio mass of grain and straw were taken from each plot during harvest, oven dried the whole material at 65±5^{0}C for 48 hours and grounded in such a manner that passed through 0.5 mm mesh sieve. The Kjeldahl procedure (Jackson method, 1973) [9] was followed for estimation of nitrogen content, Olsen's method (Olsen *et al.*, 1982) [10] for phosphorus content and Flame photometer (Hanway and Heidel, 1952) [7] for Potassium content in plant. Nutrient use efficiencies such as agronomic efficiency, partial factor productivity and nutrient harvest index were calculated by using the formula (Bhatnagar, A., 2014) [2].

Results and Discussion

Table 1: Nitrogen content (%) and uptake (kg/ha) in grain and straw as influenced by fertilizer doses and seed treatments

Fertilizer doses (150:60:40 NPK Kg/ha)	N-content (%)		Uptake (Kg/ha)		Total uptake (Kg/ha)
	Grain	Straw	Grain	Straw	
Full dose of fertilizer	1.64	0.66	85.93	60.32	146.25
¾ dose of fertilizer	1.58	0.57	77.42	41.52	118.94
½ dose of fertilizer	1.50	0.51	64.05	35.77	99.82
No fertilizer	1.42	0.44	43.73	22.13	65.86
SEm±	0.013	0.012	1.489	1.38	0.99
C.D. (P= 0.05)	0.058	0.057	6.94	6.44	4.6
C. V. (%)	2.96	6.8	4.75	7.31	8.07
Seed treatments					
Control	1.50	0.50	59.85	34.35	94.2
Plasma	1.54	0.55	68.83	43.17	112.0
Nano Chitosan	1.60	0.59	74.56	50.97	125.5
SEm±	0.006	0.004	4.039	1.85	4.91
CD (P=0.05)	0.058	0.013	NS	6.14	NS
C.V. (%)	3.25	7.9	7.12	11.09	3.45
Interaction	NS	NS	NS	NS	NS

Nitrogen content (%), uptake in grain, straw and total nitrogen uptake (Kg/ha)

The data presented in Table 1 revealed that nitrogen content and uptake in grain and straw was maximum at full dose of fertilizer, which was at par with 3/4th dose of fertilizer but significantly higher than ½ and no dose of fertilizer. Among seed treatments, nanochitosan treated seeds @ 50 ppm found maximum nitrogen content, which was statistically at par with plasma treated seeds for 6 minutes but significantly higher over control (Table 1 and Fig. 3). The probable reason was maximum availability and mobilization of nutrients towards grain and straw but there was no any significant difference between interaction effect of fertilizer doses and seed treatment methods.

Phosphorus content (%), uptake in grain, straw and total Phosphorus uptake (Kg/ha)

The maximum phosphorus uptake in grain was found in full dose of fertilizer with nanochitosan treated seeds @ 50 ppm, which was significantly higher over other treatments (Table 2 and Fig. 3). But there was no any significant difference between fertilizer doses and seed treatments to phosphorus content in straw. however, maximum phosphorus uptake in straw was observed with ½ dose of fertilizer plus plasma treated seed, that can be due to plasma enhanced nutrient absorption and translocation effectively. Similar results were attributed by Sadhu *et al*. (2017) [14].

Table 2: Phosphorus content (%) and uptake (kg/ha) in grain and straw as influenced by fertilizer doses and seed treatments

Fertilizer doses (150:60:40 NPK Kg/ha)	P-content (%)		Uptake (Kg/ha)		Total uptake (Kg/ha)
	Grain	Straw	Grain	Straw	
Full dose of fertilizer	0.37	0.15	19.38	13.71	33.09
¾ dose of fertilizer	0.33	0.13	16.17	11.24	27.41
½ dose of fertilizer	0.29	0.24	12.38	19.96	32.34
No fertilizer	0.25	0.08	7.7	4.02	11.72
SEm±	0.002	0.069	0.254	5.309	0.710
C.D. (P= 0.05)	0.010	NS	1.185	NS	3.311
C. V. (%)	4.64	7.2	5.94	12.32	6.64
Seed treatments					
Control	0.28	0.09	11.17	6.18	17.35
Plasma	0.31	0.22	13.85	17.27	31.12
Nano Chitosan	0.35	0.14	16.31	12.09	28.4
SEm±	0.003	0.059	0.213	4.201	0.785
CD (P=0.05)	0.011	NS	0.705	NS	2.600
C.V. (%)	11.03	7.2	4.6	14.95	9.79
Interaction	NS	NS	NS	NS	NS

Potassium content (%), uptake in grain, straw and total Potassium uptake (Kg/ha)

Maximum potassium content as well as uptake in grain and straw (Table 3) was found in full dose of fertilizer, which was statistically at par with 3/4th dose of fertilizer but significantly higher than ½ and no dose of fertilizer. Within seed treatments, nanochitosan treated seeds @ 50 ppm gave maximum potassium content, which was significantly higher than control and plasma treated seeds (Table 3 and Fig 3). These findings were concurrent with the findings of Rico *et al.* (2011) [12].

Table 3: Potassium content (%) and uptake (kg/ha) in grain and straw as influenced by fertilizer doses and seed treatments

Fertilizer dose (150:60:40 NPK Kg/ha)	K-content (%)		Uptake (Kg/ha)		Total uptake (Kg/ha)
	Grain	Straw	Grain	Straw	
Full dose of fertilizer	0.44	1.55	23.05	141.67	164.72
¾ dose of fertilizer	0.42	1.48	20.58	128.02	148.60
½ dose of fertilizer	0.37	1.42	15.79	118.14	133.93
No fertilizer	0.32	1.36	9.86	68.41	78.27
SEm±	0.003	0.004	0.305	1.528	1.765
C.D. (P= 0.05)	0.013	0.017	1.423	7.125	8.227
C. V. (%)	11.84	8.61	6.3	13.4	8.2
Seed treatments					
Control	0.36	1.42	14.36	97.55	111.91
Plasma	0.38	1.46	16.98	114.61	131.59
Nano Chitosan	0.41	1.49	19.11	128.73	147.84
SEm±	0.002	0.003	0.356	0.049	3.502
CD (P=0.05)	0.006	0.010	1.180	5.024	11.598
C.V. (%)	11.30	6.59	7.4	16.638	8.02
Interaction	NS	NS	NS	NS	NS

Agronomic efficiency (Kg grain/Kg nutrient applied)

Agronomic efficiency for nitrogen, phosphorus and potassium was found maximum with 3/4th dose of fertilizer along with nanochitosan treated seeds (Table 4), which was statistically at par with ½ dose of fertilizer plus plasma treated seeds. It might be due to better uptake of N, P and K with nanochitosan and plasma because nanochitosan increased movement of nutrients due to their smaller size and high surface energy (Ruixin *et al.*, 2019) [13] whereas plasma cause oxidation of seed coat and increased easy penetration of nutrient into the plant system.

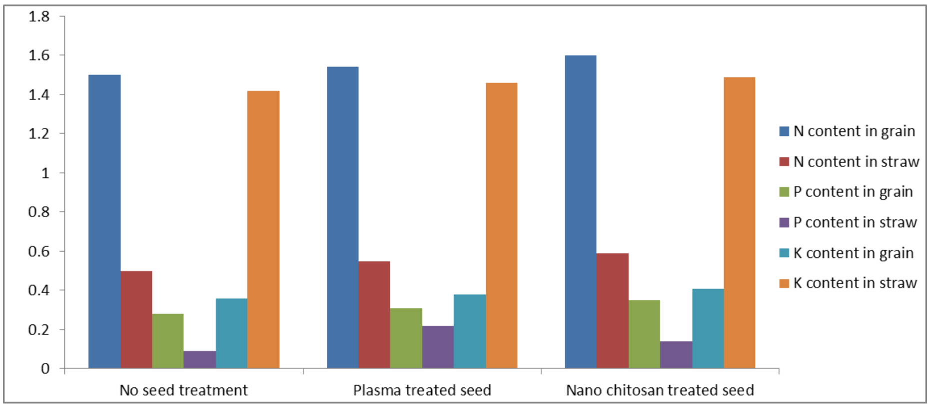

Fig 3: Effect of control, plasma and nanochitosan seed treatments on nitrogen, phosphorus and potassium content of grain and straw

(a) (b) (c)

Fig 4: Field representation of experiment after 90 days after sowing

Table 4: Effect of fertilizer doses and seed treatments on agronomic efficiency, partial factor productivity and nutrient harvest index

Fertilizer doses (150:60:40 NPK Kg/ha)	Agronomic efficiency (Kg grain/Kg nutrient applied)			Partial factor productivity (Kg grain/Kg nutrient applied)			Nutrient harvest index		
	N	P	K	N	P	K	N	P	K
Full dose of fertilizer	12.67	31.80	47.70	33.44	83.59	125.39	0.56	0.58	0.14
¾ dose of fertilizer	16.33	39.72	60.63	43.99	109.99	164.99	0.54	0.56	0.13
½ dose of fertilizer	13.49	38.77	55.58	54.55	136.37	204.55	0.52	0.55	0.12
No fertilizer	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.49	0.13
SEm±	0.55	1.36	2.70	0.26	0.65	0.97	0.012	0.011	0.012
C.D. (P= 0.05)	2.54	6.34	12.59	1.21	3.02	4.53	NS	0.051	NS
C. V. (%)	12.58	12.07	10.15	11.93	8.91	11.92	5.51	4.90	12.91
Seed treatments									
Control	9.01	22.01	32.76	30.58	76.45	114.68	0.49	0.50	0.11
Plasma	10.25	27.63	44.26	33.62	82.97	126.07	0.54	0.55	0.13
Nano chitosan	12.60	33.06	45.91	34.79	88.04	130.47	0.56	0.58	0.15
SEm±	0.59	1.07	1.81	0.67	1.32	2.52	0.007	0.008	0.01
CD (P=0.05)	1.94	3.55	5.98	2.22	4.36	8.35	0.022	0.026	0.034
C.V. (%)	15.62	11.01	12.46	5.75	4.51	5.76	3.59	4.09	12.06
Interaction	NS	NS	NS	NS	S	NS	NS	NS	NS

Partial factor productivity of N, P and K (Kg grain yield/Kg nutrient applied)

The results presented in Table 4 revealed that maximum partial factor productivity of N, P and K was recorded at ½ dose of fertilizer along with nanochitosan treated seeds, which was statistically at par with plasma treated seeds for 6 minutes but significantly higher than rest of treatments.

Nutrient harvest index (%)

There was no any significant difference between nutrient harvest index for nitrogen and potassium, but within seed treatments, nanochitosan treated seeds @ 50 ppm was found maximum, which was statistically at par with plasma treated seeds for 6 minutes but significantly higher over control (Table 4). These findings are similar with (Chibu *et al.*, 2001) [4] Nutrient harvest index for phosphorus was recorded maximum with full dose of fertilizer and nanochitosan, which was statistically at par with 3/4th and ½ dose of fertilizer in addition to plasma but significantly higher than other treatments.

Conclusion

Nanochitosan and plasma enhanced nutrient absorption as well as translocation from source to sink in plant system and also improved sink strength of crop that enables for nutritional benefit among grains even after 25% reduction in recommended doses. Hence, both technologies can be help full to remove malnutritional problem of in the country.

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