International Journal of Agriculture Sciences
ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 10, Issue 20, 2018, pp.-7401-7405.
Available online at https://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217

Research Article

BALANCE SHEET OF N AND S RECYCLING AND PRODUCTIVITY OF INDIAN MUSTARD UNDER DIFFERENT NUTRIENT TREATMENTS AND PLANT GROWTH REGULATORS

DUBEY R.K.[1], MUNDRA S.L.[1], DHAKER R.C.*[2] AND DUBEY S.K.[3]
[1]Department of Agronomy, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, 313 001, Rajasthan, India
[2]Agriculture Research Officer (Agronomy) Dy. Director of Agriculture (Exten.), Udaipur, Rajasthan, India
[3]ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Chhalesar, Agra 282 006, Uttar Pradesh, India
*Corresponding Author: Email - rameshagro2011@gmail.com

Received: October 15, 2018; Revised: October 25, 2018; Accepted: October 26, 2018; Published: October 30, 2018

Abstract: Oilseed productivity in the country is being constrained by shrinking soil fertility, inadequate and imbalanced fertilization and climatic constraints. PGRs mitigate abiotic and biotic stress and a number of laboratory/pot culture studies confirm to a strong synergistic interaction between auxins and brassinosteroids/BR but field studies in this line are meager. Therefore, N and S dynamics mainly soil depletions, crop uptake and unaccounted losses were studied through balance sheet method under different nutrient treatments and plant growth regulators/PGRs to achieve sustained higher productivity of Indian mustard during winters of 2012 and 2013 in Udaipur region. Eight nutrient treatments *i.e.* 75 and 100% recommended dose of fertilizers/RDF and their combinations with 5 t farm yard manure ha^{-1}/FYM, bio-fertilizers (*Azotobacter* + PSB) and FYM+ bio-fertilizers in main plots and four PGRs (water spray, BR 0.5 ppm, Indole acetic acid/IAA 50 ppm and BR 0.5 + IAA 50 ppm) in sub plots were evaluated in a split plot design replicated thrice. Results show that 100% RDF + FYM+ bio-fertilizers outperformed other nutrient treatments in pooled seed and stover yield (3231 and 13604 kg ha^{-1}), crop N and S uptake(157.23 and 79.43 kg ha^{-1}, respectively) and available soil N and S at crop harvest (272.53 and 25.44 kg ha^{-1}, respectively). Among PGRs, BR + IAA registered significantly higher pooled seed and stover yield (2922 and 12379 kg ha^{-1}) and crop N and S uptake (142.11 and 69.52 kg ha^{-1}, respectively).

Keywords: Brassinolide, Indole acetic acid, Indian mustard, Integrated nutrient management, Residue recycling

Citation: Dubey R.K., *et al*., (2018) Balance Sheet of N and S Recycling and Productivity of Indian Mustard under Different Nutrient Treatments and Plant Growth Regulators. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 10, Issue 20, pp.- 7401-7405.
Copyright: Copyright©2018 Dubey R.K., *et al*., This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Introduction

Current seed yield of Indian mustard, the 2^{nd} largest oilseed crop in India, needs to be raised from 1145 to 2562 kg ha^{-1} by 2030 for substantially decreasing or zeroing huge Indian edible oil import bill which exceeds 9 million US $ [1]. India's edible oil self sufficiency critically links to a comprehensive technological address to major agronomical constraints being mostly either nutritional or stress oriented in nature. Negative annual imbalance between crop nutrient removals and additions in country tolls to about 8-10 million tons (Mt) for macronutrients while per ha N imbalance being about 16 kg apart from a severe imbalance in N: P_2O_5: K_2O: S ratio of agricultural soils (14.7:5.1:1.1:1.0). Also, majority of Indian soils have limited/constrained availability of N and S, important for sustainable higher oilseed yields. This requires substantially raising quantity and efficiency of nutrient additions to an optimum level [2]. Promoting regular use of optimum blend of slowly mineralizing plant or animal based manures, readily nutrient releasing chemical fertilizers and bio-fertilizers in different crops through integrated nutrient management (INM) can be a promising, innovative and environmental friendly option as the practice encourages sustainable agriculture through potentially enhancing plant performance and crop yield, improving nutrient and water use efficiencies, enabling lower chemical fertilizer use and maintaining soil fertility [3]. Therefore, worth of probable and feasible INM modules have to be comprehensively assessed especially from point of view of crop nutrient recovery, maintenance of soil fertility, nutrient losses and productivity of crops and crop rotations in various agro-climates and soil groups in India. This article discusses N and S dynamics grossly estimated under different nutrient treatments and PGRs through preparing balance sheets by utilizing data on nutrient additions, crop nutrient removals and soil fertility before sowing and at crop harvest on medium clay loam soils of Udaipur region.

PGRs mitigate different abiotic and biotic stresses by improving various physiological, metabolic, structural and other plant processes [4-6]. Enhancement in yield of crops on use of PGRs links to harmonization of physiological processes, specific simulation of harvestable organs and improvement in source to sink relations [7]. BRs and auxins independently improve growth and productivity of crops on account of diverse key physiological reasons *viz*. maintenance of stability of photosynthetic membrane [8], stress tolerance through elevated levels of anti-oxidative enzymes and decrease in proline and H2O2 levels [9], improvement in cellular and physiological functions *etc*. Auxins also improve various key physiological processes *viz*. levels of nitrate reductase and carbonic anhydrase, chlorophyll content, photosynthetic rate, soluble proteins, root sugars, dry biomass *etc*. [10]. A strong synergistic interaction between BR and auxin is widely reported on basis of laboratory/pot studies [11,12] but exploring benefit of such interaction have yet not been explored in field studies globally. Also, comparative performance of PGRs on crop nutrient recovery, yield levels, maintenance of soil fertility *etc* widely lacks in India. Therefore, this study is presenting influence of different nutrient treatments together with independent and interactive effects of BR and auxin on gross N and S dynamics together with yield of Indian mustard on clay loam soils of North West (NW) India beset with high temperature at pod formation and grain filling stages of test crop.

Materials and Methods

A 2- year field experiment was conducted at Udaipur (24035'N latitude and 73.42'E longitude) in Rajasthan state of India in agro-climatic zone IV a/ Sub-Humid Southern Plains and Aravali Hills at an elevation of 582.5 m above mean sea level during winters of 2012 and 2013.

Table-1 Available N balance sheet (kg ha^{-1}) under different nutrient and PGR treatments in Indian mustard

Treatments	Initial available soil N status (A)			N added B	Total crop N uptake C			Expected available N balance D= (A+B-C)			Actual available N balance E			Pooled apparent gain/ loss F=E-D	Pooled actual gain/ loss G=E-A
	2012	2013	Pooled		2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled		
Nutrient treatments															
N_1	282.42	284.59	283.50	45.00	101.62	103.54	102.58	225.80	226.05	225.92	237.20	235.26	236.23	10.31	-47.27
N_2	282.16	283.97	283.06	60.00	122.09	124.55	123.32	220.07	219.42	219.74	242.80	245.25	244.02	24.28	-39.04
N_3	281.98	284.16	283.07	52.83	116.21	118.45	117.33	218.60	218.54	218.57	250.36	253.89	252.13	33.56	-30.94
N_4	282.67	283.58	283.12	67.83	131.17	132.79	131.98	219.33	218.62	218.97	258.61	264.04	261.33	42.36	-21.79
N_5	282.56	283.79	283.17	45.00	110.62	113.03	111.83	216.94	215.76	216.34	247.05	250.53	248.79	32.45	-34.38
N_6	282.68	284.16	283.42	60.00	128.66	130.11	129.39	214.02	214.05	214.03	254.58	259.95	257.26	43.23	-26.16
N_7	282.64	284.13	283.39	52.83	138.74	142.07	140.41	196.73	194.89	195.81	260.32	263.59	261.95	66.14	-21.44
N_8	282.89	283.67	283.28	67.83	156.96	157.50	157.23	193.76	194.00	193.88	270.11	274.96	272.53	78.65	-10.75
SE+/-	3.23	2.73	2.11		3.47	3.56	2.48	2.79	2.55	1.89	2.45	3.06	1.96	2.03	1.58
CD (P = 0.05)	NS	NS	NS		10.51	10.80	7.20	8.47	7.74	5.48	7.44	9.30	5.69	5.88	4.58
PGRs															
G_0	282.24	284.51	283.37	56.42	112.82	115.62	114.22	225.84	225.31	225.57	253.68	257.01	255.35	29.78	-28.02
G_1	282.56	283.76	283.16	56.42	129.01	130.89	129.95	209.97	209.29	209.63	252.68	253.73	253.20	45.72	-29.96
G_2	282.38	283.84	283.11	56.42	121.09	122.4	121.75	217.71	217.86	217.78	252.97	257.06	255.02	35.42	-28.09
G_3	282.82	283.91	283.37	56.42	140.12	142.11	141.12	199.12	198.22	198.67	251.17	255.93	253.55	56.35	-29.82
SE+/-	1.04	0.53	0.59		1.38	1.37	0.98	1.59	1.66	1.22	1.27	2.10	1.23	1.69	1.23
CD (P=0.05)	NS	NS	NS		3.91	3.85	2.74	4.35	4.38	1.05	NS	NS	NS	4.74	NS

Table-2 Available S balance sheet (kg ha^{-1}) under different nutrient and PGR treatments in Indian mustard

Treatments	Initial available soil S status A			S added B	Total crop S uptake C			Expected available S balance D= (A+B-C)			Actual available S balance E			Pooled apparent gain/ loss F=E-D	Pooled actual gain/ loss G=E-A
	2012	2013	Pooled		2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled		
Nutrient treatments															
N_1	33.58	33.86	33.72	30.00	47.20	48.94	48.07	16.38	14.92	15.65	20.03	20.30	20.17	4.52	-13.55
N_2	33.61	33.91	33.76	40.00	61.04	62.45	61.75	12.57	11.46	12.01	21.83	22.14	21.99	9.98	-11.77
N_3	33.66	33.97	33.81	32.50	56.44	57.47	56.95	9.72	9.00	9.36	21.82	22.02	21.92	12.56	-11.89
N_4	33.63	33.91	33.77	42.50	65.99	66.58	66.29	10.14	9.83	9.98	23.81	24.16	23.98	14.00	-9.79
N_5	33.73	33.97	33.85	30.00	53.76	54.41	54.08	9.97	9.56	9.77	22.70	22.90	22.80	13.03	-11.05
N_6	33.60	34.01	33.80	40.00	64.59	64.83	64.71	9.01	9.18	9.09	24.54	24.71	24.62	15.53	-9.18
N_7	33.67	34.01	33.84	32.50	69.26	70.07	69.67	-3.09	-3.56	-3.33	23.11	23.28	23.20	26.53	-10.64
N_8	33.66	33.97	33.82	42.50	79.17	79.68	79.43	-3.01	-3.21	-3.11	25.29	25.59	25.44	28.55	-8.38
SE+/-	0.11	0.12	0.08		1.98	1.99	1.40	1.93	1.95	1.37	0.23	0.29	0.18	1.48	0.15
CD (P= 0.05)	NS	NS	NS		5.99	6.01	4.05	5.85	5.90	3.97	0.69	0.87	0.53	4.28	0.43
PGRs															
G_0	33.59	34.01	33.80	36.25	55.64	57.36	56.50	14.20	12.90	13.55	22.71	23.01	22.86	9.31	-10.94
G_1	33.68	34.01	33.84	36.25	64.20	64.90	64.55	5.73	5.36	5.54	22.89	23.04	22.96	17.42	-10.88
G_2	33.59	33.91	33.75	36.25	59.63	60.18	59.90	10.21	9.98	10.10	23.03	23.23	23.13	13.03	-10.62
G_3	33.70	33.87	33.79	36.25	69.25	69.78	69.52	0.70	0.34	0.52	22.95	23.27	23.11	22.59	-10.68
SE+/-	0.04	0.07	0.04		0.69	0.70	0.49	0.70	0.69	0.48	0.10	0.15	0.09	0.49	0.09
CD (P=0.05)	NS	NS	NS		1.96	2.00	1.38	1.93	1.96	1.36	NS	NS	NS	1.38	NS

The experimental soil was well drained clay loam (sand: 38.20%, silt: 25.70% and clay: 36.10%) having a mean alkali pH 8.2, bulk density 138 Mg/ m^3, soil organic carbon 0.66%, field capacity 28.6%, permanent wilting point 12.4% and available N, P_2O_5 and S to a level of 283.2, 20.13 and 33.26 kg ha^{-1}, respectively. Gross sub plot (5.0 x 3.6 m) were reduced to 4.0 x 2.4 m for estimation of yield and deriving soil samples at crop harvested on turning uniform pale in color after removal of border rows. Certified seed of Indian mustard (Cv. Laxmi) was drilled in rows 30 cm on 24.10.2012 and 26.10.2013 in a field under continuous maize crop for previous five rainy seasons. A plant to plant spacing of 10 cm was manually maintained within the each row while carrying out the hoeing and weeding at 20 days crop stage. Mean N: P_2O_5:S composition of oven dried FYM estimated by standard methods *i.e.* Snell and Snell, 1949, Richards, 1968 and Tabatabai and Bremmer, 1970 was 0.47, 0.23 and: 0.15%, respectively [13-15]. Soil samples randomly collected by augur in furrow slice (0-15 cm) at three random points in each sub plot were thoroughly mixed and finally 100 g soil was carefully derived following repeated half accept and half reject method. Available soil N before sowing and at crop harvest was determined by alkaline $KMnO_4$ method [16] while available soil S was estimated by 0.15% $CaCl_2$ extraction method [17]. N and S content in seed and stover were determined after oven drying the plant material at 65°C till a constant weight was achieved, grinding the material to required fineness and estimating N through Nessler's reagent colorimetric method (Snell and Snell, 1949) and S by turbidity method. Nutrient uptake by seed and stover independently were calculated by multiplying nutrient content and dry seed/ stover yield and converting it in kg ha^{-1}. Data were statistically analyzed for each year of study and on pooled basis deploying standard procedure for analysis of variance (ANOVA) of split plot design [18].

Results and Discussion

Available N balance in furrow slice

Different nutrient and PGR treatments registered identical initial available N in furrow slice (A values) whileN applied (B values) were indifferent among PGRs only (Table 1). Nutrient treatments widely varied in B values (maximum variation: 22.83 kg N ha^{-1} between N1, N5 and N2, N6). Crop N uptake (C values) significantly varied among nutrient and PGR treatments (maximum variation: 54.65 kg N ha^{-1} between N1and N8at only 22.83 kg N ha^{-1} difference in B values). Notably, 31.82 kg N ha^{-1} additional pooled crop N uptake was recorded over and above B value underN8. This can be linked to lower pooled actual N loss/G values (corresponding variation: 36.52 kg N ha^{-1}), N benefits from Azotobacter, N mineralization from residues recycled at end of previous crop and crop N uptake from beyond furrow slice depth.

Table-3 Seed and stover yield (kg ha^{-1}) and net return (Rs ha^{-1}) under different nutrient and PGR treatments in Indian mustard

Treatments	Seed yield			Stover yield		
	2012	2013	Pooled	2012	2013	Pooled
N_1	2236	2270	2253	9650	9801	9726
N_2	2601	2640	2621	11054	11198	11126
N_3	2500	2541	2521	10764	10909	10836
N_4	2762	2787	2774	11668	11750	11709
N_5	2384	2438	2411	10406	10486	10446
N_6	2707	2733	2720	11492	11540	11516
N_7	2930	2977	2953	12505	12690	12598
N_8	3228	3235	3231	13606	13602	13604
SE+/-	65	63	45	287	274	198
CD(P=0.05)	198	190	131	869	831	574
G_0	2452	2503	2478	10509	10705	10607
G_1	2733	2763	2748	11647	11750	11698
G_2	2582	2607	2595	11091	11102	11097
G_3	2907	2937	2922	12326	12432	12379
SE+/-	26	28	19	122	129	89
CD(P=0.05)	75	81	54	346	366	249

Significantly higher pooled C values are also supported by minimum depletion in A values(-10.75 kg ha^{-1}) and significantly higher pooled E value under N8which can be linked to more root growth/ramification at higher N level [19] that strengthens the possibility of crop N uptake from below the furrow slice depth. Pooled C values differed significantly even when B values did not differ in treatments where Azotobacter was used *viz*. N1 and N5, N2 and N6, N3 and N7 and N4 and N8and an enhancement equal to 9.25, 6.07, 23.08 and 25.25 kg N ha^{-1} was observed in latter treatments, respectively. Treatment 75% RDF + bio-fertilizers registered significantly higher pooled C value over 75% RDF but 100% RDF and 100% RDF + bio-fertilizers were indifferent. This shows higher N benefits from Azotobacter at lower chemical N fertilization level. Use of 75% RDF + FYM + bio-fertilizers registered significantly higher pooled C value over 100% RDF + bio-fertilizers which pin points on favorable effect due to gradual and consistent release of N from FYMthat also serves as a source of energy/carbon/nutrients to soil/bio-fertilizer microbes [20]. Azotobacter improves overall crop N uptake and yield through favorable interactions among biologically active substances, root exudates and ammonia [21] besides, uptake of Fe^{3+} and other cationic micro-nutrients is enhanced through production of siderophores [22]. Also, PSB releases IAA, siderophores, hydrocyanic acid and ammonia which promotes root proliferation, nutrient uptake and crop yield [23]. The effect of synergistic interaction between bio-fertilizers and FYM in this study exceeded independent influence of either FYM or bio-fertilizers in terms of pooled C values. There is more N benefit (20-40 kg ha^{-1} year^{-1}) on integration of bio-fertilizers with FYM apart from enhancement in root and shoot growth, maintenance of soil N and higher crop yield [24]. Pooled C values as a per cent fraction of A + B values ranged from 31.23 (N1) to 44.78 (N8) and 33.61 (water spray) to 41.53 (BR + IAA) but higher pooled E values over their respective pooled D values suggest for precise future studies involving entire root zone to quantify N mining from beyond furrow slice depth. The results on furrow slice N at crop harvest also corroborate with findings of Castle et al., 2003 and Mandal et al., 2010. Treatments involving 100% RDF (N2, N4, N6, N8) registered significantly higher pooled E values over their 75% RDF counterparts (N1, N3, N5, N7) indicating a situation of better maintenance of furrow slice Non supplementing N through both inorganic and organic sources. Nevertheless, pooled C values exceeded corresponding B values in various nutrient and PGR treatments (range in kg ha^{-1}: 57.58 in N1 to 89.40 in N8 and 57.80 in water spray to 84.70 in BR + IAA) which indicates over exploitation of furrow slice but real depletion in A values was much lower than what actually indicated by pooled D values. The pooled F values (kg ha^{-1}) were positive and ranged from 10.31 (N1) to 78.65 (N8) and 29.78 (water spray) to 56.35 (BR + IAA). Among PGRs, variation between maximum and minimum pooled E values was narrow (2.15 kg N ha^{-1}) and not significant, therefore, PGRs neither favored build up nor depletion of furrow slice N. However, all nutrient and PGR treatments invariably registered negative pooled G values (kg ha^{-1}) which pin points on a variable loss of N from furrow slice on account of high mobility and gaseous losses of N. In this backdrop, it can be concluded that so far as maintenance of furrow slice N on cultivation of Indian mustard in Udaipur region is concerned, use of only chemical fertilizers was most detrimental followed by use of bio-fertilizers and FYM in combination with either 100 and 75% RDF. Use of 100% RDF+ FYM+ bio-fertilizers showed minimum depletion in A values hence, this INM module can be regarded as the most suitable for N supplementation to Indian mustard in Udaipur zone.

Available S balance in furrow slice

Pooled A, B and C values of available furrow slice S followed a trend identical to N (Table 2). Pooled C values followed significant variation in manner chemical fertilizer + FYM + bio-fertilizers> chemical fertilizer + FYM = chemical fertilizer + bio-fertilizers> chemical fertilizer. Among nutrient treatments, N8 registered significantly higher pooled C value which pin points on worth of FYM in releasing S apart from favorable influence brought about by a synergistic interaction between FYM and soil/bio-fertilizer microbes which can be important in S mineralization from previous crop/weed/other residues. Integrating FYM with either 75 or 100% RDF recorded significantly higher pooled crop S uptake over their respective sole fertilizer counterparts but variations in pooled C values on combining FYM or bio-fertilizer with chemical fertilizer was at par. This pin points on effect of medium state of soil organic carbon (about 0.66%) at study site. Pooled C values as a percent fraction of A + B ranged between 75.44 (N1) to 105.02% (N7) and 80.66 (water spray) to 99.26 (BR + IAA), which is a very high figure. Since no S deficiency symptoms were noticed on mustard plants in either any nutrient or PGR treatment, therefore, a critical appraisal of sources capable of supplementing soil S is attended here under. It has worth to mention that experimental site hada high chance of hugeS mineralization from large quantity of weed/crop residues which is plowed back at maize harvest, about one month before sowing of Indian mustard [25]. Also, deep rooted Indian mustard can derive S from beneath furrow slice zone. S balance sheet reveals that N7 and N8treatments have slightly negative while other nutrient treatments were variably positive in pooled D values which indicates situation where furrow slice S was insufficient to meet out pooled crop S uptake under N7 and N8. However, pooled E values were clearly higher than respective pooled D values. Thus, there was only a variable over exploitation but under no condition a cent per cent depletion of furrow slice S since F values (E-D) was positive in all the treatments. Indirectly this pin points on crop S mining from beyond furrow slice zone and/or S mineralization from residues. Status of available soil S closely interlinks with state of organic matter which can constitute up to 50% of total soil S. SO_4-2 production depends on hydrolysis of ester component of organic matter by sulfatase enzyme. Also, medium soil organic matter at study site can support production of SO4-2 ions via all three established routes depending upon C: S ratio of residues *viz*. (1). HI reducible S having C-O-S linkages (2). Carbon bound S of amino acids, sulfoxides, sulfones and sulfinic acids and (3). S contained in residues. C: S ratio <200 is ideal for mineralization of S from residues but this ratio was further narrow (<50) in residues recycled and applied FYM in this study. Other possible reasons behind exceptionally high S recovery by Indian mustard can consist of 1. Higher S mineralization in standing crop over fallow due to presence of plant root exudates, sugars, amino acids *etc*. 2. Less chances of SO4-2 leaching under controlled irrigation and leached SO4-2 interception by deep tap mustard roots and 3. Low volatile S loss on aerated soils at low daily temperature (5-25°C). As such, foregoing discussion comprise of convincing situations that can supporta high soil S availability and consequently an exceptionally high S recovery by Indian mustard in this study. Significant variations in pooled C values among PGRs (BR + IAA> BR> IAA> water spray) can be linked to fact that BR and auxins enhance growth including root growth/biomass over water spray [26]. Avery high pooled biological yield itself confirms to situation of overcrowding/high intra-specific competition which envisages a high chance of extension of crop roots beyond furrow slice zone in search of growth resources (nutrients and moisture). The root: shoot ratio of a plant species is in nearly limited range; hence higher stover yield itself confirms to a higher root biomass. S balance sheet prepared for furrow slice though reasonably concludes effects of different treatments on crop S recovery, S build up/ depletions, in situ/ex situS losses *etc* but detailed future studies must involve S mining from entire the crop root zonefor a clear and valid conclusion.

Yield levels

Pooled yield levels significantly improved on raising S application through combining FYM with either 75 or 100% RDF over their sole RDF treatments (Table 5). This indicates that S response exceeded old recommendation (100% RDF) in high yielding Indian mustard variety Laxmi. Among nutrient treatments N8registered significantly higher pooled seed and stover yield on account of significantly higher pooled crop N and S uptake (Table). These results on yield levels are in close conformity with findings of Aulakh, 2010 [27] and other workers *viz*.80-100 kg N ha^{-1} [28] and 60 kg S ha^{-1} [29]. Thus, supplementing N and S can significantly improve growth and yield of Indian mustard within optimum fertilization limits due to major role and demand of nutrients under reference. Supplementing N enhances activity of N assimilating enzymes (nitrate/ nitrite reductase, glutamine/ glutamate synthetase); improves level of total sugars, ascorbic acid, phenols and proline and increases availability of metabolite to flowers and pods [30]. Biologically Sis a pre-requisite for biosynthesis of variety of bio-molecules *viz*. cystine and cysteine, co-enzyme A (regulates synthesis of fatty acids), iron-S clusters, polysaccharides, lipids, thiamine and biotine, glutathione, phyto-chelatins, allyl Cys sulfoxides, glucocinolates and chlorophyll (being a constituent of ferridoxin). Physiologically, S regulates biosynthesis of proteolytic and nitrogenase enzymes and conductance of redox cycle, xenobiotic detoxifications, oxidation of intermediates of citric acid cycle, assimilation of N by Azotobacter *etc*. [31]. PGRs also significantly influenced pooled yield levels in manner BR + IAA> BR> IAA> water spray due to variations in their influences on physiology and metabism of plants. Significantly higher pooled yield level under BR + IAA can be linked to a strong synergistic interaction between BR and auxin where level of auxin controls endogenous level of BR and vice versa. There is also a considerable cross talk/ multi-level interaction between BR and auxin that critically controls and profoundly promotes cell division, vascular bundle formation and synthesis of bio-molecules (chlorophyll, monosaccharide, proteins *etc*.) apart from promotion of lateral root growth and control of metabolism [32]. Superiority of BR over IAA can be linked to a diverse variety of plant processes that this steroidal lactone regulates *viz*. transcription and translation, membrane stability, osmosis, stomatal conductance, control of plant processes at enzyme level, maintenance of hormonal balance and H+ pump activation, stimulation of cell enlargement, cell division, anti-oxidative enzymes (catalase, peroxidase, superoxide dismutase, tocophenols, trocophenols, trocotrienols, ascorbic acid, beta carotein *etc*.), biosynthesis of cell wall, chlorophyll, vascular bundle differentiation, pollen tube growth, micro-tubular organization and transport of assimilates from one part to another *etc*. As such, BR improve anti-oxidative defense system of plants; bio-synthesis of total proteins and nucleic acid and photosynthesis [33-36]. BR significantly improves growth and yield of Indian mustard over IAA on account of higher chlorophyll content, photosynthetic rate and carbonic anhydrase activity. IAA enhances growth and productivity of crop plants over water spray on account of variety of plant functions which are mediated by auxins.

Conclusion

On the pooled basis of different nutrient treatments, N8 recorded significantly highest grain, stover yield, actual gain and loss of N and S and in case of PGRs G3 found significantly highest grain and stover but it was fail actual gain and loss of N and S in Rajasthan.

Application of research: This study is presenting influence of different nutrient treatments

Research Category: Plant nutrition

Acknowledgement / Funding: Authors are thankful to Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, 313 001, Rajasthan, India. Authors are also thankful to ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Chhalesar, Agra 282 006, Uttar Pradesh, India

***Principal Investigator or Chairperson of research: Dr R C Dhaker**
University: Maharana Pratap University of Agriculture and Technology, Udaipur, 313 001, Rajasthan
Research project name or number: Research station trials

Author Contributions: All author equally contributed

Author statement: All authors read, reviewed, agree and approved the final manuscript

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

References

[1] Hedge D.M., Sudhakar Babu S.N., Rana D.S. and Vyas A.K. (2012) Indian Journal of Agronomy, 57,58-62.
[2] Tandon H.L.S. (2007) Soil nutrient balance sheets in India, Importance, status, issues and concerns. www.ipni.net
[3] Wu Wei and Ma Buoluo (2015) Science of Total Environment, 512-513, 415-417.
[4] Castle J., Montoya T. and Bishop G.J. (2003) Selected physiological responses of BR, a historical approach. In, S Hayat and A Ahmad (Eds.) BR. Bioactivity and Crop Productivity. Kluwer Academic Publishers, Dordrecht-Boston-London. pp. 45–68.
[5] Haubrick L.L. and Assmann S.M. (2006) Plant Cell & Environ. 29, 446–457.
[6] Biesaga Koscielniak J., Dziurka M., Ostrowska A., Mirek M., Koscielniak J. and Janeczko A. (2014) Australian Journal of Crop Science, 8,378-388.
[7] Rathke G.W., Behrens T. and Diepenbrock W. (2006) Agricultural Ecosystems and Environment, 117, 80-108.
[8] Choudhary S.P., Yu J.Q., Yamaguchi Shinozaki K., Shinozaki K. and Lam Son P.T. (2012) Trends in Plant Science17,594-605.
[9] Dobrikova A. G., Vladkova R. S., Rashkov G. D., Todinova S. J., Krumova S. B. and Apostolova E. L. (2014) Effects of exogenous 24-epibrassinolide on the photosynthetic membranes under non-stress conditions. Plant Physiology and Biochemistry, 80, 75-82.
[10] Gadallah M. A. A. (2000) Journal of Arid Environment 44, 451-467.
[11] Bao F., Shen J. J., Brady S. R., Muday G. K., Asami T. and Yang Z. B. (2004) Plant Physiology, 134, 1624-1631.
[12] Bajguz A., Piotrowska and Niczyporuk A. (2013) Plant Physiology and Biochemistry 71, 290-297.
[13] Snell P.D. and Snell G.T. (1949) Colorimetric method of analysis, 3rd ed. Vol. II-D, Van Mastrand Co., Inc. New York.
[14] Richards L.A. (1968) Diagnosis and Improvement of Saline and Alkaline Soils. USDA Handbook No. 60, Oxford and IBH Pub. Co., New Delhi 97-98.
[15] Tabatabai M.A. and Bremner J.M. (1970) Agronomy Journal62, 805-806.
[16] Subbiah B.V. and Asija G.L. (1956) Current Science, 25,259-260.
[17] Williams C. H. and Steinberg A. (1959) Australian Journal of Agricultural Research, 10,340-352.
[18] Gomez K.A. and Gomez A.A. (1984) Statistical Procedures for Agricultural Research. 2nd Edition. An International Rice Research Institute Book. A Wiley Interscience Publication. John Wiley and Sons, New York.
[19] Mandal K.G., Hati K.M., Mishra A.K. and Bandyopadhyay K.K. (2010) Irrigation Science, 28,271-280.
[20] Chand Subhash and Ram D. (2008) Environment and Ecology, 26,43-46.

[21] Van Loon L.C. (2007) European Journal of Plant Pathology 119,243–254.
[22] Crowley D.E. and Kraemer S.M. (2007) Function of siderophores in the plant rhizosphere. In, The Rhizosphere, Biochemistry and Organic Substances at the Soil–Plant Interface (Pinton, R. et al., eds), pp. 73–109, CRC Press.
[23] Taghavi S. (2009) Applied Environmental Microbiology75, 748–757.
[24] Mrkovacki N. and Milic V (2001) Annals of Microbiology51,145-158.
[25] Chalka M.K. and Nepalia V. (2005) Indian Journal of Agronomy, 50, 119-122.
[26] Hayat Shamsul, Mori M., Fariduddin Q., Bajguz A. and Ahmad A. (2010) Indian Journal of Plant Physiology15, 99-109.
[27] Aulakh Milkha S. (2010) Integrated nutrient management for sustainable crop production, improving crop quality and soil health and minimizing environmental pollution. In, proceeding of. 19th World Congress of Soil Science, Soil Solutions for Changing World, 1-6 August, 2010. Brisbane, Australia, Published on DVD.
[28] Singh R. Kumar and Singh A.K. (2014) Indian Journal of Agricultural Science, 84,142-148.
[29] Meena D.S., Teterwal J.P. and Baldev Ram (2013) Indian Journal of Agronomy 58, 96-99.
[30] Colnenne C., Meynard J.M., Roche R. and Reau R. (2002) European Journal of Agronomy, 17, 11–28.
[31] Havlin John L., Tisdale Samuel L., Beaton James D. and Nelson Werner L. (2007) Soil fertility and fertilizers: An Introduction to Nutrient Management. Pearson Education Inc., Upper Saddle River, New Jersey 07458, U.S.A.
[32] Halliday K. J. (2004) Current Biology, 14, R1008-R1010.
[33] Hola D. (2011) BR and photosynthesis. In, BR: A class of plant hormones (Editors Shamsul Hayat and Aqil Ahmad). ISBN: 978-94-007-0188-5 Springer Dordrecht Heideberg London New York, 243-288.
[34] Ahmad A., Hayat S., Fariduddin Q. and Ahmad I. (2001) Photosynthetica, 39, 565-568.
[35] Ali B., Hasan S. A., Hayat S. and Ahmad A. (2007) Journal of Plant Biology, 34, 29-33.
[36] Kumar C.S., Singh A., Sagar R.K. and Maurya J.N. (2011) Indian Journal of Agronomy, 58, 96-99.