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Review Paper

Role of plant nutrients in enhancing productivity and managing diseases of oilseed Brassica

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Abstract

Rapeseed-mustard production and productivity commonly influenced not only the damage caused by biotic stresses but also by the nutrient supply for plant growth. Nutrient stress or surplus in plants causes them less vigorous and more susceptible to different diseases. High yields are normally obtained on deep fertile topsoil without a compact layer to facilitate root growth, and a porous crumb structure of the uppermost soil layer for rapid germination of the small seed of rapeseed-mustard. This is assisted by a neutral soil reaction and sufficient organic matter for optimal biological activity. The oilseed brassica crops damaged by several diseases, including Alternaria blight, white rust, downy mildew, Sclerotinia rot, and powdery mildew caused yield losses of 47%, 35%, 40% and 17%, respectively, which are of vital importance. The deficiency of nutrients has negative impact on plant health and yield level. In case of infection due to a disease, plants encounter the pathogen by producing inhibiting compounds although their production and transport is mainly dependent upon plant nutrients. Healthy plants are less susceptible to infections. Nutrient management of both micro and macronutrient is a challenging aspect for sustainable production in India because most of soils are nutrient deficient. The role of integrative plant nutrition is an important component in sustainable agriculture, because it is more cost effective and also environment friendly way to control plant disease. Adequate nutrients can achieve disease control to a certain level, but further control could be gained through cultural practices or conventional organic biocides that are eco-friendly. The advancements in averting such looses thus have lots of bearing on the growers, consumers and the society. The paper reviews the role of plant nutrient in managing the diseases and enhancing rapeseed-mustard production under Indian condition.

Introduction

Relationship between plants, nutrients, and disease pathogens are very complex and not completely understood. Nutrition, although frequently unrecognized, has always been a primary component of disease control. Most soils and climatic conditions where brassica crops are grown contain an abundance of disease pathogens. On the most basic level, plants suffering a nutrient stress will be less vigorous and more susceptible to a variety of diseases. In this respect, all nutrients affect plant disease. However, some nutrient elements have a direct and greater impact on plant diseases than others.

Oilseeds constitute the second largest agricultural commodity in India after cereals accounting for nearly 5% of gross national product and 10% of the value of all agricultural products. Among the oilseeds, rapeseed-mustard group of crops occupies prominent position in the country contributing nearly 21.6% and 23.1% to the total oilseed cropped area and production, respectively. The total production from India is about 6.7 mt of rapeseed-mustard next to China (11-12 mt) and EU (10–13 mt) with an important contribution in world rapeseed-mustard industry (Shekhawat *et al*., 2012). Among the top 10 rapeseed-mustard growing countries India, China and Canada together account for 63.2% of total harvested area and 54.2% of total production. The oleiferous Brassica species, commonly known as rapeseed-mustard, are one of the economically important agricultural commodities. Rapeseed-mustard comprising eight different species viz. Indian mustard, Toria, Yellow Sarson, Brown Sarson, Gobhi Sarson, Karan rai, black mustard and Taramira, are being cultivated in 53 countries all over the world. The mustard can be grown under rain fed or irrigated conditions but it grown alongwith other crops and considered mainly as a rainfed crop. It is an herbaceous plant with tap root reaching upto height of 30 to 100 cm in length. Its flower is yellow in color with corolla regular (actinomorphic), yellow, approximately 1 cm wide, petals four, 6–10 mm long, sepals 4, stamens 6, of which 4 long and 2 short. Gynoecium fused a single carpel. It can grow on pH of 5.5 to 8.8. *Brassica rapa* is extensively cultivated as an oil crop and vegetable especially in Asia. Among the major oil crops, oilseed Brassica is of increasing importance. The oil extracted from the seeds containing 40 percent oil is used for salad oil, as a cooking medium and for fuel. The residues referred to as oilseed cake are protein rich animal feed. In many parts of South Asia, rapeseed mustard is an important winter-season crop that is grown either alone or as a secondary intercrop in wheat fields. With new varieties of winter rape, including hybrids, high seed yields of 4–5 tonnes/ha are attainable compared with average yields of 3–3.5 tonnes/ha in Europe. High yields are normally obtained on deep fertile topsoil without a compact layer to facilitate root growth, and a porous crumb structure of the uppermost soil layer for rapid germination of the small seed. This is assisted by a neutral soil reaction and sufficient organic matter for optimal biological activity.

Nutrient requirements

Oilseed rape needs an abundant and timely nutrient supply for good growth and high seed yield. The total nutrients absorbed by a crop producing 4.5 tonnes of seed per hectare are of the order (in kilograms): N 300–350, P_2O_5 120–140, K_2O 300–400, Mg 30–50 and S 80–100. The seeds contain the majority of nutrients except for K, which remains mainly in the straw. Out of the total nutrient uptake, about 20 percent takes place before winter and 50 percent in spring before flowering. In subtropical north India, the total nutrient removal per tonne of seed production by mustard was of the following order (Aulakh, 1985): Macronutrients (kg): N 32.8, P_2O_5 16.4, K2O 41.8, Mg 8.7, Ca 42.0 and S 17.3; Micronutrients (g): Fe 1123, Zn 100, Mn 95 and Cu 17.

The crop yield losses on field and during post harvest period caused by various diseases and insect pests are of paramount importance. The annual loss can go up to 30%. Even if a conservative figure of 15% is considered, it translates into a loss of 30 million tons of food grain, 4 million tons of oilseeds, 86 million tons of sugarcane and 23 million tons of fruits and vegetables annually. An annual loss of 60,000 crores has been estimated in India (Kumar and Saxena, 2009). Plant protection is thus challenging, interesting and important science. The amount of food loss averted is a direct contribution to the food basket of hungry millions. The advancements in averting such looses thus have lots of bearing on the growers, consumers and the society. Hence, an attempt was made to review the works on role of plant nutrient in managing the diseases and enhancing mustard production under Indian condition.

The deficiency of nutrients causes negative impact on plant health and yield level. In case of infection due to a disease. The disease inhibiting compounds are produced in plants but their production and transport is dependent upon plant nutrients (Meena *et al.*, 2015). Management of both micro and macronutrient is a challenging aspect for sustainable production in India because most of soils are nutrient deficient. Corrent status of micronutrients deficiency in soils of Rajasthan is very critical among other states of India where about 45% of the total oilseed brassica crops cultivated (Table 1). The role of integrative plant nutrition is an important component in sustainable agriculture, because it is more cost

Table 1: Current status of micronutrients deficiency in soils of different States (AICRP-MPSE 2015)

State	DTPA-extractable micronutrients					Hot water soluble Boron	
	No. of samples	Percent sample deficient				No. of samples	Percent sample deficient
		Zn	Fe	Cu	Mn		
Andhra Pradesh	6723	22.3	16.8	1.0	1.7	3216	2.8
Assam	5216	25.6	0.0	3.8	0.0	5216	11.9
Bihar	12671	37.9	9.9	1.9	7.4	12671	36.3
Chhattisgarh	4731	20.1	6.8	3.2	14.1	-	-
Gujarat	5470	23.1	23.9	0.4	6.3	5470	17.9
Haryana	5673	15.3	21.6	5.2	6.1	5673	3.3
Himachal Pradesh	3189	11.1	0.8	2.1	3.5	3189	32.0
Jharkhand	1443	20.3	0.0	0.5	0.0	1443	56.0
Karnataka	7468	44.0	13.5	3.5	2.7	-	-
Kerala	894	18.3	1.2	1.3	11.4	894	24.7
Madhya Pradesh	11695	66.9	10.2	0.6	1.8	4734	1.7
Maharashtra	8278	54.0	21.5	0.2	3.8	489	54.8
Odisha	2349	22.7	1.8	0.3	1.1	2349	52.5
Punjab	2181	16.6	6.2	3.6	15.2	1083	17.5
Rajasthan	5226	75.3	85.5	35.5	63.7	-	-
Tamil Nadu	31080	65.5	10.6	13.0	7.9	31080	19.9
Telangana	4799	26.9	17.0	1.4	3.8	2776	16.1
Uttar Pradesh	4788	33.1	7.6	6.3	6.5	4323	16.2
Uttarakhand	2575	9.6	1.4	1.4	4.7	2575	7.0
West Bengal	2363	11.9	0.0	1.2	0.9	1849	46.9
India	127812	43.4	14.4	6.1	7.9	88030	20.6

effective and also environment friendly way to control plant disease. Adequate nutrients can achieve disease control to a certain level, but further control could be gained through cultural practices or conventional organic biocides.

Multi-nutrient deficiencies in soils of mustard growing areas

Assessment of multi-nutrient deficiencies in different agro-ecological sub-regions has been done at IARI. The results indicated that simultaneous deficiency of two or more nutrients were very common in all the agro-ecosystems. Soil samples exhibited these kinds of complex soil fertility disorders. Data illustrated in Figure 1 indicate that one-fourth of the samples of Hisar district of Haryana suffered from simultaneous inadequacy of NPK. Other prominent inadequacy combinations were NPKFe (16%), NP (14%) and NPFe (13%). A number of multi-nutrient deficiency combinations of smaller magnitude representing 1 or 2% of the total samples were also recorded (not included in Fig 1) (Dwivedi *et al.,* 2009).

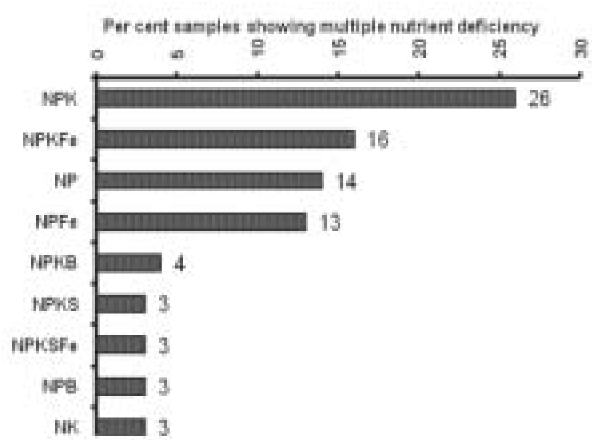

Figure 1: Extent of multi-nutrient deficiency in soils representing Rajasthan Bagar & North Gujarat Plain (AESR 2.3; Village Pattan; District Hisar)

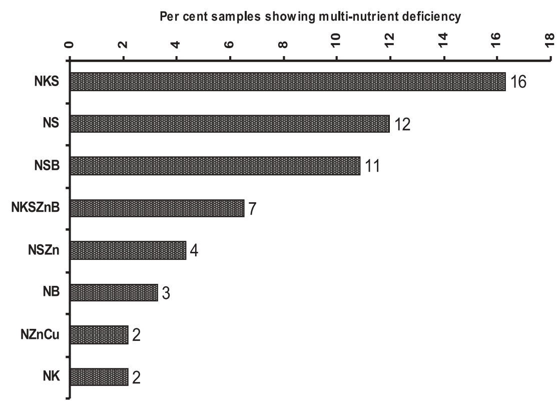

Figure 2: Extent of multi-nutrient deficiency in North Punjab Plain & Ganga-Yamuna Doab (AESR 4.1; Village Lohtaki; District Gurgaon)

Similarly, in case of Gurgaon district the simultaneous deficiencies of 2 to 5 nutrients were observed. More than twenty multi-nutrient deficiency combinations were noticed, of which NKS (16%), NS (12%), NSB (11%) and NKSZnB (7%) were the prominent ones (Fig 2).

1. Role of nutrients in mustard productivity and plant health

The productivity of rapeseed-mustard mainly affected by many technological components as described in Table 2 (DRMR, 2013). Nutrient supply to plants play very important role in plant growth and ultimate crop yield and quality of produce. When crops fail to absorb any nutrient in sufficient quantities, the metabolism disturbances occur and crops exhibit specific hunger signs. These hunger signs are called deficiency symptoms, which appear depending upon the mobility of nutrient in plants. Deficiency symptoms of nitrogen, phosphorus, potassium, magnesium, molybdenum and zinc appear first on older leaves (Table 3). The deficiency symptoms of calcium, boron, manganese iron and sulphur appear first on new leaves and buds. On the other hand, if some of these nutrients are present in excess they produce toxicity symptoms and require immediate adoption of corrective measures.

Table 2: Impact of technological components on the productivity of rapeseed-mustard (DRMR, 2013)

Technological components	Increase in productivity (%)
Improved varieties	9-45
Plant protection measures	7-24
Recommended Fertilizers	16-18
Sulphur nutrient	9-16
Thinning to remove excess plants/sqm	13-16
Thiourea spray at flowering	10-12
Timely weeding	11-27
Chemical weed control	14-35

Nitrogen requirements are higher than the N removal figure of 30–35 kg N per tonne of seed. About 30-40 kg N/ha is sufficient for fertilization in autumn. Oilseed rape prefers nitrate N. However, ammonium nitrate is also a good source of N. The recommended N rates for seed yield of about 4 tonnes/ha are:

1. a first application of 80–100 kg N/ha early in spring on soils that can supply about 40 kg N/ha;

2. a second application of 60–80 kg N/ha at the start of elongation;

3. a third application of 25 kg N/ha at the beginning of flowering for very high yields.

Correspondingly less N is required for lower yield levels. Oilseed rape tends to leave large amounts of N in the soil after harvest (both as nitrate and as crop residues). These may amount to more than 100 kg/ha N. With good N management, it is possible to keep the mineral N residue below 50 kg N/ha, which is tolerable from a pollution point of view, or to utilize the residual amount by the following crop. In semi-tropical north India, the irrigated crop can respond to 240 kg N/ha on coarse-textured soils that are low in organic matter. Under dryland conditions, 30–50 kg N/ha is usually optimal. Application of N through AS or of P through SSP is advantageous in S-deficient soils. Response to P is determined by soil P status, moisture availability and yield level. As a general guideline, N and P_2O_5 are recommended in a ratio of 2:1. The supply of major nutrients should be ample during the growing season, even during short periods of stress caused by dryness or cold.

Table 3: Deficiency symptoms of macronutrient

Macronutrient	Symptoms
N	Nitrogen deficient plants initially show anthocyanin pigmentation on leaves. Gradually fully mature older leaves turned to a light purple colour and finally to uniform purple yellow colour. In due course the affected leaves dried up and withered. *Control* : Apply 50-100 kg N ha^{-1}
P	Initially bluish dark patches appeared on the fully matured older leaves of phosphorus deficient plant and gradually turned into pale colour and finally necrosis of upper half leaves.*Control* : Apply 50-60 kg P_2O_5 ha^{-1}
K	The K-deficient plants showed stunted growth, leaves become small, fleshy, deformed and curled downward. The chlorosis followed by necrosis starts from margins of lower and/ or middle and gradually spread to the inner surface of leave. Leaf edge scorch in sever deficiency. *Control* : Apply 40-50 kg K_2O ha^{-1}

Application should be made at sowing, but a split application with part applied in spring is needed on light soils where losses may occur in winter. The amounts of P and K required depend on the nutrient removal and soil nutrient supply.

Sulphur deficiency in soil cause drastic loss to oilseed Brassica seed yield. Various S deficiency symptoms (general yellowing, shrinking, cupping or purpling of leaves, reddish-purple discoloration of stems or pods, delay of flowering and maturation, and small and poorly filled pods) usually occur when the crop is moderately to severely lacking in S. On slightly deficient soils, the amount should be about 30% higher, and on soils in the sufficiency range about 50% less. Brassicas have the highest requirement of S among field crops. Application of S fertilizers into S deficient soils helps in better emergence of seed. The optimal rate of S to be applied depends on the soil S status, yield potential and the level of N applied. A proper N:S balance is important for mustard production. When N is in excess (high N:S ratio), there is insufficient S to combine with the N to make protein, and thus non-protein N accumulates. A useful guideline is to add N and S fertilizer in a 7:1 ratio, which is approximately the ratio needed by the mustard plant. There has been research into using the N:S ratio during tissue testing to determine S status. However, the N:S ratio of mustard tissue has not proved reliable for predicting S status. The N:S ratio only indicates the relative proportions of N and S in the plant, and does not indicate their actual magnitudes. Therefore, if mustard tissue tests show an optimal ratio of 7:1, there are three possibilities: both N and S levels are optimal, excessive, or deficient.

In coarse-textured soils, 20–50 kg S/ha may be applied. Still there is no need of S fertilization in industrial areas because of the large amounts of S deposited through the atmosphere as a result of industrial pollution. In less industrialized parts of the country this was not so. Since atmospheric additions have fallen, S deficiencies have become widespread and rates of 20–80 kg S/ha are required in order to obtain 0.5% S in the young leaves. About 10 kg of S are required per tonne of seed yield. In the case of an acute deficiency, foliar spray with a soluble S fertilizer can be used as a quick remedy. Malhi *et al.* (2004) reported that application of S @ 15-20 kg ha^{-1} is considered to be efficient in prevention S deficiency in soils (Meena *et al*., 2006a). It was also reported that oil content increased significantly with application of S (20 kg ha^{-1}) but oil content responded negatively with increasing N levels (Ahmad *et al.*, 2007).

Role of micronutrients cannot be neglected in increasing the yield level of any crop. Zinc is also involved in the synthesis of Indole Acetic acid, so deficiency leads to changes in the growth habit of plants, including rosetting and reduction in leaf size (Grant and Bailey, 1993). Field experiments showed an average positive response of mustard to Zn fertilization of 270 kg ha^{-1}in India. It was reported that application $ZnSO_4$ @ 3 kg ha^{-1} significantly increased yield level over an application of $ZnSO_4$

@ 2 and 4 kg ha^{-1} (Azam *et al.*, 2013). Zinc deficiency can be a problem that can be corrected by soil application of 5-10 kg Zn/ha. Where the previous crop in the rotation has received Zn application or 10–15 tonnes of FYM/ha have been used, the application of Zn fertilizer can be omitted. Zinc and Fe enriched FYM also evaluated to increase the seed yield and quality of mustard. Zn and Fe use efficiency and micronutrients availability in soil, results showed that application rate of chemical Zn and Fe fertilizers could be minimized through enrichment techniques and achieved good seed yield and quality (Meena *et al*., 2006b, Meena *et al*., 2006c, Meena *et al*., 2008b). Meena *et al*. (2015) concluded that different nutrient management options decreased Alternaria blight over check, and significantly increased seed yield, test weight and quality of seeds**.** Molybdenum is also another micronutrient for the growth of *B. rapa*. The molybdenum deficiency causes various symptoms turned chlorotic, cupping, marginal scorcbing and loss of lamina in younger leaves, application of Mo can considerably increase growth (Chaterjee *et al*., 1985). Although only 10–15 g Mo/ha are required by oilseed rape, some soils do not supply this small amount. The need for Mo fertilizers must be based on diagnostic methods. Soil application of Mo increased mustard seed yield and quality (Mehta *et al*., 2013). Boron application prevents sterile florets and pod development (Nutall *et al*., 1987). Because oilseed rape has a B requirement that is at least five times higher than that of cereals, 0.5 kg B/ha should be applied in combination with other fertilizers on deficient soils. The Mn requirement is high and an application of about 1.5 kg Mn/ha is recommended in many areas, and foliar spraying is effective. Because of the high soil reaction needed by oilseed rape, Mn availability is lowered and deficiencies frequently limit yields. Copper is also an important micronutrient as it is a component of enzymes and helps in suppressed diseases and increase crops yields.

Table 4: Deficiency symptoms of micronutrients

Micronutrients	Symptoms and control
Fe	Chlorosis starts from the base and spread towards lamina. Bleached leaves, silique number and size decrease and appear chlorotic. *Control*: Foliar spray 0.5-1.0% ferrous sulphate solution 3-4 times at weekly intervals.
Mn	Chlorosis in leaves, followed by developing small greyish-brown spots which coalesce to form large necrotic lesions. *Control*: Spray 0.5-1.0% manganese sulphate 2-3 times at weekly interval is better than its soil application @ 40-50 kg/ha.
Cu	Young leaves develop interveinal chlorosis. Growth of plants is also reduced which is more pronounced at the time of flowering. Inflorescence is very poorly developed. Pod formation and seed setting are also reduced. *Control*: Spray 0.2% copper sulphate solution 2-3 times at weekly intervals
Zn	There is retardation of growth, after 20 days of sowing. Leaves are small in size with pinkish margin. Interveinal tissues turn yellowish white to papery white, with veins remaining green. Severely affected leaves die. Flowering and fruiting is delayed. *Control:* Zinc deficiency can be corrected by both soil application @ 5-6 kg Zn/ha as basal or foliar spray of 0.5% zinc sulphate solution along with 0.25% slaked lime.
Mo	Growth is markedly reduced and plants develop foliar symptoms like cupping, marginal scorching and loss of lamina. *Control*: Soil application of molybdenum (1.0 kg Mo/ha)
B	Cell walls are dramatically affected by B deficiency. This shows up as cracked, hollow or corky stems. The cell wall diameter and proportion of plant dry weight increases under B deficiency. Most plant B is complexed with organic compounds in the cell walls, apparently serving a nonspecific structural role. *Control*: 0.5-2.5 kg B/ha. Soil application is better than foliar spray or seed-soaking.

On the basis of soil fertility status as indicated in figure 2, an experiment was conducted to addressed the multi-nutrient deficiencies in soil of Gurgaon district of Haryana. Mustard seed yield under site-specific nutrient management (SSNM) (that included on average 120 kg N + 60 kg P_2O_5 + 100 kg K_2O + 40 kg S/ha along with carryover effect of S, Zn and B applied to preceding crop) ranged between 2.76 and 3.11 t/ha in different experiments with a mean of 2.88 t/ha, which was 83 to 92% (mean 85%) greater than that recorded in farmers' fertilizer practices (FFP) (Table 5**).** Although, mustard is not known to be as responsive to fertilizer K as cereal, yet inclusion of K in FFP or state recommendation (SR) increased its yield by an average of 0.15 to 0.25 t/ha in the present studies, possibly due to extremely low K content of soils. Yield differences between SR+K and SR were greater compared with those between FFP+K and FFP, indicating that a crop well-fertilized with NP (and preferably other deficient nutrients) would respond better to fertilizer K compared with a crop receiving N alone or N and P at a lower rate as in case of FFP. The disease incidences were also less under SSNM as compared to FFP (Dwivedi *et al.,* 2009).

3. Integrated nutrient management and crop yield

Integrated nutrient management (INM) is basically done to maintain soil fertility and nutrient supply at an optimum level to increase crop productivity. There are numerous studies conducted on impact of INM on crop yields. Several studies shows that yield can be increased to considerable extent on application of organic and inorganic nutrients altogether. It was

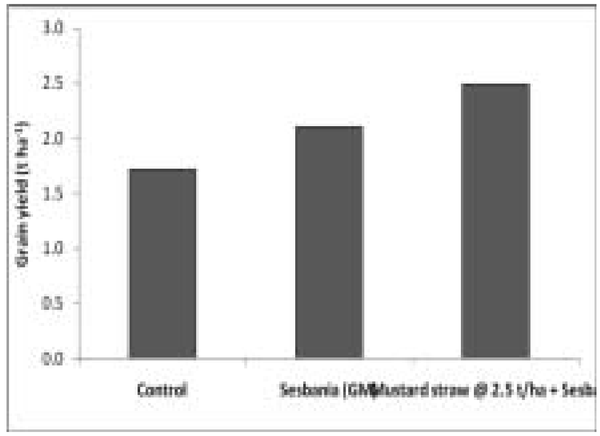

Figure 3: Effect of integrated nutrient management on seed yield of mustard (DRMR, 2013)

reported that application of farmyard manure (FYM) in Gangetic plains of India during winter crop with 50–75% of recommended fertilizers in all the crops that are in rotation can cause significant increase in production level (Khanda *et al.,* 2005, Mandal *et al.,* 2013). Mitra and Mandal (2012) stated that use of 10 t FYM ha^{-1}along with 50% NPK could considerable increased in yield of *B. rapa*. It was found that there was 21.1 fold increase in *B. rapa* with continuous application of balanced inorganic (100% NPK) + lime + biofertilizer + FYM as compared to the control (Saha *et al.,* 2010). It was reported that application of 10 t FYM ha^{-1} alongwith 100% NPK (N-P-K80-17.2-33.2 kg ha^{-1}) significantly increased crop yields (Mandal and Sinha, 2004). Meena *et al*. (2013) noticed that application of FYM and sewage sludge increased yield and quality of mustard on a Typic Haplustept Zn deficient soil (Meena *et al*., 2008a). Use of *Sesbania* green manuring alongwith mustard straw @ 2.5 t

Table 5: Seed yield response of mustard to fertilizer options (06 on-farm experiments averaged)

Treatment	Seed yield (t/ha)	Yield increase over FFP	
		(t/ha)	%
SSNM	2.88	1.32	84.6
TY	2.45	0.89	57.1
TY+Micro	2.76	1.20	76.9
SR	1.93	0.37	23.7
SR+K	2.18	0.62	39.7
FFP+K	1.71	0.15	9.6
FFP	1.56	-	-

ha^{-1} can significantly increase seed yield by 44.8% over control (DMRM, 2013) in respective of fertilizer NPK application (Fig 3).

4. Role of nutrients in disease control

Composition of macro and micronutrient elements in host plant has a great significance in resistance and susceptibility in various host pathogen combinations (Rathi *et al*., 2015). Most important nutrients which provide disease resistance in plants are K, S, Ca, Cu, B, Mn and Si. Out of that silicon are not essential but beneficial in disease resistance. Sufficient quantities of all essential nutrients must be delivered to the plants for better performance otherwise plant will suffer and produce less than their potential. Most of Indian soils are suffering from multi-nutrient deficiencies and nutrient elements deficient are N, P, K, S, Zn and B (Dwivedi and Meena, 2015). The nutrients required for plant growth are classified into macro- and micronutrient. The nutrients as N, P, and K are classified as primary while S, Ca and Mg are secondary macronutrient. The nutrients as Zn, Fe, Mn, Cu, B, Mo, Cl and Ni are essential micronutrients required for plant growth. Nutrients (S, Zn and B) application into soil could be the best options for the management of Alternaria blight of mustard (Haider *et al*., 2014). The deficiency of nutrients including K, S, Zn and Cu increases the Alternaria blight susceptibility in *B. juncea* plants, in case of infection plant natural defence mechanism gets triggered (Meena *et al*., 2011; 2015).

Macronutrients

Adequate nitrogen supply is essential for healthy plant growth but excessive nitrogen supply makes the plants succulent and susceptible to infection**.** Level of nitrogen and potassium affect the severity of diseases caused by parasites (Table 6). Adjusted to the timing of optimum N-demand of the crop, timing of N-doses effectively increases production efficiency of winter oilseed rape. Apart from these integrated N-management strategies soil cultivation, seeding, application of plant protection agents and plant growth regulators as well as soil fertilization and harvesting are closely interacting with N-efficiency of winter oilseed rape. Altogether, amount and timing of N fertilizer as well as cultivar selection had the strongest influence on productivity followed by smaller effects due to previous crop and type of fertilizer. Using N-efficient management strategies like choice of variety, form and timing of N-application adapted to site conditions, a remarkable reduction in fertilizer N-demand (up to 50% of fertilizer input) is possible leading to lower N-balance surpluses in winter oilseed rape production, thus minimizing environmental pollution (Rathke *et al*., 2006).

Presence of adequate phosphorus imparts resistance to the plant against many diseases. Applied phosphorus has been shown to allow crops to better tolerate diseases. Potassium plays a very important roles in stress tolerance of plants to both adverse conditions like biotic (insects, pathogens etc.) and abiotic (heat, cold, drought etc.). Potassium provides disease resistance mainly through two processes like mobilization of plant defense system and increases cuticle thickness which inhibits the pathogen infection. Potassium enhances plant resistance to many diseases of rapeseed such as black spot. Application of NK (N 90 kg ha^{-1}+K 40 kg ha^{-1}) in decreasing the severity of black spot diseases was increasingly more pronounced as compared to application of PK (P 40 kg ha^{-1}+K 40 kg ha^{-1}), NP and K (40 kg ha^{-1}) applications. The decrease in the severity of Black spot disease because K resulted in higher production of phenolics in plants which inhibited conidial germination and decreased sporulation of *A. brassicae*. Decrease in Alternaria blight severity by applying 40 kg K ha^{-1} in soil increased seed yield over control plants (Sharma and Kolte, 1994).

Walker and Hooker (1945) observed the effect of potassium, attaining a constantly higher disease index at higher concentrations of potassium. These works indicate that potassium may be necessary for the growth of *P. brassicae* as well as its host and provide early evidence that disease development can be manipulated by plant nutrition.

Sulphur deficiency in crop plants plays a greater role and results in reduction of leaf area, seed number, seed weight, delayed floral initiation and anthesis (Jackson, 2000). Application of S, in the form of Gypsum as basal dose applied @ 40 kg ha^{-1},

Table 6: Tentative summary of the effect of nitrogen and potassium levels on the severity of diseases caused by parasites (Marschner, 1995)

Pathogen and Disease	Nitrogen level		Potassium level	
	Low	High	Low	High
Obligate parasites				
Albugo (Rust)	+	++	++++	+
Erysiphe graminis (powdery mildew)	+	++	++++	+
Facultative parasites				
Alternaria spp. (leaf spots)	+++	+	++++	+
Fusarium oxysporum (wilts and rots)	+++	+	++++	+
Xanthormonas spp. (spots and wilts)	+++	+	++++	+
Sclerotinia sclerotiorum (white rot)	+	+++	++++	+

resulted into less severity of white rust and Alternaria blight in comparison to control treatment (Rathi *et al*., 2015). The use of elemental sulphur (S°) is the well known as a fungicide and newest phytoalexin in plant-pathogen interactions which was reported to produce as a component of active defense to fungal pathogens (Williams and Cooper, 2004). The plants require S for the synthesis of glucosinolates reported that help in plant's defence mechanism against fungi (Meena *et al*., 2015). It was reported that soil application of S was found to increase resistance against different fungal pathogens in many crops (Klikocka *et al*., 2005). Calcium is an important for the stability and function of plant membranes and when there is Ca deficiency there is membrane leakage of low-molecular weight compounds, e.g. sugars and amino acids, from the cytoplasm to the apoplast, which stimulate the infection by the pathogens (Marschner, 1995). Calcium provides strong defense system to plants through fortifies the middle lamella (middle lamella = calcium pectate) and reduces degradation by pathogens (especially soft rot bacteria that attack cacti and succulents.). More calcium in middle lamella also reduces pathogen enzyme activity like Pectolytic enzyme (Polygalacturonase) activity, and stops motile spores (*Phytophthora* and *Pythium*). Calcium also increases plant membrane stability and reduces *Rhizoctonia* enzyme activity (Marschner, 1995). Adequate levels of calcium can reduce clubroot in crucifer crops (broccoli, cabbage, turnips, etc.). The disease is inhibited in neutral to slightly alkaline soils (pH 6.7 to 7.2). A direct correlation between adequate calcium levels, and/or higher pH, and decreasing levels of *Fusarium* occurrence has been established for a number of crops. Calcium has also been used to control soil-borne diseases caused by *Pythium*, such as damping off. A study conducted by Rathi *et al*. (2015) showed that Ca spray in the form of slaked lime @ 1% at 50 days was not effective in reduction of white rust and Alternaria leaf blight of mustard plant. Numerous studies suggest that calcium or magnesium in lime may affect disease development independent of pH (Myers and Campbell 1985; Murakami *et al*., 2002b). This interrelationship between mineral nutrients in the soil system is complex. Palm (1963) provided one of the earliest reports of an interrelationship between calcium and boron affecting the potential ability of lime to control clubroot.

Micronutrients

The effect of micronutrients on reducing the severity of diseases (Table 7, 8) can be attributed to the involvement in physiology and biochemistry of the plant, as many of the essential micronutrients are involved in many processes that can affect the response of plants to pathogens (Marschner, 1995). Micronutrients can also affect disease resistance indirectly, as nutrient-deficient plants not only exhibit an impaired defence response, but often may also become more suitable for feeding as many metabolites such as reducing sugars and amino acids leak outside the plant cell. For example, plants suffering from a Zn deficiency showed increased disease severity after infection by *Oidium* spp.

(Bolle-Jones and Hilton, 1956). It was also observed that in B-deficient wheat plants, the disease severity was several-fold higher than that in B-sufficient plants, with the fungus spreading more rapidly than in B-sufficient plants (Schutte, 1967). Systemic acquired resistance (SAR) may be involved in the suppression of plant diseases by micronutrients. Reduction in disease severity has been reported in other crops after a single foliar application of H_3BO_3, $CuSO_4$, $MnCl_2$ or $KMnO_4$, which provided systemic protection against powdery mildew in cucumber plants (Reuveni *et al.*, 1997a, b; Reuveni and Reuveni, 1998). The same authors also suggested that application of nutrients such as Mn, Cu and B can exchange and therefore release Ca^{2+} cations from cell walls, which interact with salicylic acid and activate systemic acquired resistance mechanisms. Micronutrients play an important role in plant metabolism by affecting the phenolics and lignin content and also membrane stability (Graham and Webb, 1991). Micronutrients can affect resistance indirectly, as in deficient plants they become more suitable feeding substrate.

Zinc

Zinc was found to have a number of different effects as in some cases it decreased, in others increased, and in others had no effect on plant susceptibility to disease (Graham and Webb, 1991; Grewal *et al.*, 1996). In most cases, the application of Zn reduced disease severity, which could be because of the toxic effect of Zn on the pathogen directly and not through the plant's metabolism (Graham and Webb, 1991). Zinc plays an important role in protein and starch synthesis, and therefore a low zinc concentration induces accumulation of amino acids and reducing sugars in plant tissue (Marschner, 1995; Römheld and Marschner, 1991). As an activator of Cu/Zn-SOD (superoxide dismutase), Zn is involved in membrane protection against oxidative damage through the detoxification of superoxide radicals (Cakmak, 2000). Impairments in membrane structure caused by free radicals lead to increased membrane leakage of low-molecular-weight compounds, the presence of which favours pathogenesis (Graham and Webb, 1991; Marschner, 1995; Mengel and Kirkby, 2001). Critical Zn

Table 7: Effect of different micronutrients on white rust severity in Indian mustard

Treatments	White rust severity (%)				
	2008-09	2009-10	2010-11	2011-12	Mean
$ZnSO_4$ @15 kg ha^{-1}	30.0	34.7	42.0	41.9	37.2
Borax @ 10 kg ha^{-1}	32.2	38.3	42.5	43.7	39.2
Gypsum @15 kg ha^{-1}	28.9	33.3	37.2	40.7	35.0
$ZnSO_4$+Borax+Gypsum	23.2	28.3	35.9	37.8	31.3
Spray of Dithane M-45 @ 0.2 %	18.9	21.1	24.9	25.9	22.7
Untreated Check	33.9	43.3	48.3	48.9	43.6
CD (Pd"0.05)	4.9	3.2	2.7	2.4	1.2

Table 8: Effect of different micronutrients on Alternaria leaf blight severity in Indian mustard

Treatments	Alternaria leaf blight severity (%)				
	2008-09	2009-10	2010-11	2011-12	Mean
$ZnSO_4$ @15 kg ha^{-1}	31.9	38.2	30.7	30.4	32.8
Borax @ 10 kg ha^{-1}	33.9	39.4	31.2	31.1	33.9
Gypsum @15 kg ha^{-1}	29.4	38.3	31.4	28.1	31.8
$ZnSO_4$+Borax+Gypsum	22.1	30.0	26.4	26.5	26.3
Spray of Dithane M-45 @ 0.2 %	20.0	23.9	20.9	16.3	20.3
Untreated Check	41.1	45.0	35.0	33.3	38.6
CD (Pd"0.05)	5.4	4.6	3.0	3.4	1.5

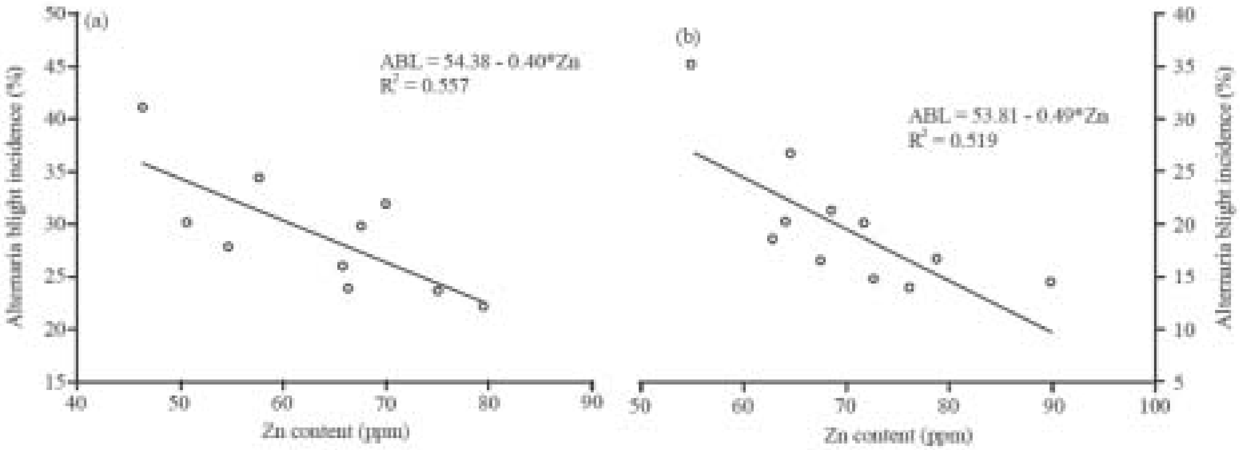

Figure 4: Effect of Zn content of Indian mustard leaves on severity of Alternaria blight

concentration (mg/kg) in mustard was reported as whole shoots, 35; leaves, 41; and seeds, 33 (Rashid *et al*., 1994) for optimum growth. It was reported that at deficient Zn concentration (0.00065 mg Zn L^{-1}) deficiency symptoms were depression in growth, short internodes, chlorosis and necrosis of mature leaves, along with development of purple pigmentation at leaf margins, which later covered the entire lamina (Chaterjee and Khurana, 2007). Application of 15 kg $ZnSO_4 ha^{-1}$ + Gypsum @ 250 kg ha^{-1} (40 kg S ha^{-1}) and also 10 kg Borax ha^{-1} + Gypsum @ 250 kg ha^{-1}as basal dose, in comparison to single treatment were effective in control of white rust (Table 7) and Alternaria blight (Table 8) of mustard plant (Rathi *et al*., 2015) in Zn, B and S deficient soil. A relationship between Zn content of Indian mustard leaves and severity of Alternaria blight of mustard (Fig 4) has been developed by Meena *et al*. (2015).

Copper

Copper increases cuticle thickness, which is barrier to infections. It is necessary for polyphenoloxidase activity. Polyphenoloxidase system produces some phytoalexins and other anti-pathogenic molecules which inhibits the growth of pathogens (Marschner, 1995). Bordeaux mixture has been successfully used for over 150 years on fruits, vegetables and ornamental plants. Bordeaux mixture is both fungicidal and bactericidal. As such, it can be effectively used against diseases such as leaf spots caused by bacteria or fungi, powdery mildew, downy mildew

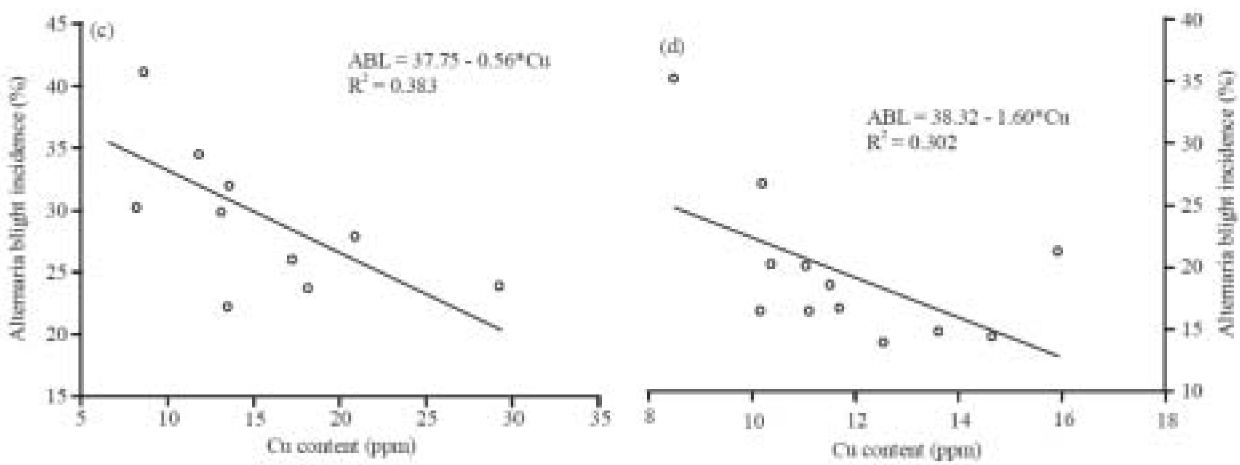

Figure 5: Effect of Cu content of Indian mustard leaves on severity of Alternaria blight

and various anthracnose pathogens. Bordeaux mixture's tenacity in adhering to plants regardless of spring rains is one reason why it is so effective. Bordeaux mixture contains copper sulfate, which is acidic, neutralized by lime (calcium hydroxide), which is alkaline. Meena *et al*. (2015) reported that increasing Cu content in Indian mustard leaves decreased severity of Alternaria blight of mustard (Fig 5).

Iron

Iron is one of the most important micronutrients for animals and humans and the interaction between Fe nutrition and human or animal health has been well studied, as it is involved in the induction of anemia. However, the role of Fe in disease resistance is not well studied in plants. Several plant pathogens, e.g. *Fusarium*, have higher requirements for Fe or higher utilization efficiency compared with higher plants. Therefore, Fe differs from the other micronutrients such as Mn, Cu and B, for which microbes have lower requirements. Addition of Cu, Mn and B to deficient soils generally benefits the host, whereas the effect of Fe application is not as straight forward as it can have a positive or negative effect on the host. Fe can control or reduce the disease severity of several diseases such as rust in wheat leaves, smut in wheat and *Colletotrichum musae* in banana (Graham and Webb, 1991; Graham, 1983). Fe can promote synthesis of fungal antibiotics by soil bacteria (Graham and Webb, 1991). Rhizosphere micro-organisms can synthesize siderophores which can lower Fe level in the soils. These siderophores can suppress germination of clamydospores of *F. oxysporum* f.sp. *cucumerinum in-vitro*. However, the production of siderophores and the antagonisms for Fe are not only mechanisms to limit the growth of any pathogenic fungus.

Manganese

Manganese is probable the most studied micro-nutrient about its effects on disease and is important in the development of resistance in plants to both root and foliar diseases (Graham and Webb, 1991; Huber and Graham, 1999; Heckman *et al*., 2003). Mn availability in the soil varies and depends on many environmental and soil biotic factors. Mn is required in much higher concentration by higher plants than by fungi and bacteria and there is opportunity for the pathogen to exploit this difference in requirement (Marschner, 1995). Manganese fertilization can control a number of pathogenic diseases such as powdery mildew, downy mildew, take-all, tan spot, and several others (Brennan, 1992; Huber and Graham, 1999; Heckman *et al*., 2003; Simoglou and Dordas, 2006). Despite the fact that Mn application can affect disease resistance the use of Mn is limited, which is due to the ineffectiveness and poor residual effect of Mn fertilizers on most soils that need Mn supplements, and is because of the complex soil biochemistry of Mn. In most soils that require addition of Mn such as calcareous soils, 90–95% of added Mn is immobilized within a week. Mn has an important role in lignin biosynthesis, phenol biosynthesis, photosynthesis and several other functions (Marschner, 1995; Graham and Webb, 1991). Mn inhibits the induction of amino peptidase, an enzyme which supplies essential amino acids for fungal growth and pectin methyl esterase, a fungal enzyme that degrades host cell walls. Manganese controls lignin and suberin biosynthesis (Römheld and Marschner, 1991; Vidhyasekaran, 1997) through activation of several enzymes of the shikimic acid and phenylpropanoid pathways (Marschner, 1995). Both lignin and suberin are important biochemical barriers to fungal pathogen invasion (Kolattukudy *et al*., 1994; Rioux and Biggs, 1994; Hammerschmidt and Nicholson, 2000; Vidhyasekaran, 1997, 2004), since they are phenolic polymers resistant to enzymatic degradation (Agrios, 2005). Lignin and suberin are believed to contribute to wheat resistance against powdery mildew and to all diseases caused by *Gaeumanomyces graminis* (Sacc.) (Rovira *et al*., 1983; Graham and Webb, 1991; Huber, 1996; Krauss, 1999). It has also been shown that Mn soil applications reduce common scab of potato (Keinath and Loria, 1996), *Fusarium* spp. infections in cotton and *Sclerotinia sclerotiorum* (Lib. de Bary) in squash (Graham and Webb, 1991; Agrios, 2005).

Boron

Boron has a direct function in cell wall structure and stability and has a beneficial effect on reducing disease severity. In several diseases, however, the function of B in disease resistance or tolerance is the least understood of all the essential micronutrients for plants. The function that B has in reducing disease susceptibility could be because of (1) the function of B in cell wall structure, (2) the function of B in cell membrane permeability, stability or function, or (3) its role in metabolism of phenolics or lignin (Brown *et al*., 2002; Blevins and Lukaszewski, 1998). Phenolics include phytoalexins and other molecules that are toxic to plant pathogens. Qinones may also form phenolics: which is also toxic to plant pathogens. Boron promotes stability and rigidity of the cell wall structure, and therefore supports the shape, and strength of the plant cell (Marschner, 1995; Brown *et al*., 2002). Furthermore, B is possibly involved in the integrity of the plasma membrane (Marschner, 1995; Brown *et al*., 2002; Dordas and Brown, 2005). Boron has been shown to reduce clubroot disease caused by *Plasmodiophora brassicae* (Woron.) in crucifers (Graham and Webb, 1991). Boron shows the development of *P. brassicae* during infection of root hairs (primary infection) and the root cortex (secondary infection) of several vegetable *Brassica* spp. In field trials, 4 kg ha^{-1} was the most effective rate that produced no phytotoxic symptoms. Clubroot severity at 6 weeks after seeding was reduced by 64% compared with a non-treated control. This indicates that B application could be an important component of an integrated management programme to manage *P. brassicae* in canola (Deora *et al*., 2011).

Chlorine

Chlorine is required in very small amounts for plant growth and Cl deficiency has rarely been reported as a problem in agriculture. However, there are reports showing that Cl application can enhance host plants' resistance to disease in which fairly large amounts of Cl are required, which are much higher than those required to fulfill its role as a micronutrient but far less than those required to induce toxicity (Mann *et al*., 2004). It has also been suggested that Cl might interact with other nutrients such as Mn. Cl has been shown to control a number of diseases such as stalk rot in corn, stripe rust in wheat, take all in wheat, northern corn leaf blight and downy mildew of millet, and septoria in wheat (Graham and Webb, 1991; Mann *et al*., 2004). The mechanism of Cl's effect on resistance is not well understood. It appears to be non-toxic *in vitro* and does not stimulate lignin synthesis in wounded wheat leaves. It was suggested that Cl can compete with NO^{-3} absorption and influences the rhizosphere pH. It can suppress nitrification and increase the availability of Mn. Furthermore, Cl ions can mediate reduction of Mn III, IV oxides and increase Mn for the plant, increasing the tolerance to pathogens.

Silicon

Although, Si is the second most abundant element in the earth's soil and is a component of plants. It is not considered to be an essential element, except for members of the Equisitaceae family (Marschner, 1995). However, when Si is added to the soil, plants low in soluble Si show an improved growth, higher yield, reduced mineral toxicities and better disease and insect resistance (Graham and Webb, 1991; Alvarez and Datnoff, 2001; Seebold *et al*., 2000, 2004). Also, in many countries crops such as rice and sugarcane which accumulate high levels of Si in plant tissue are fertilized routinely with calcium silicate slag to produce higher yields and higher disease resistance. Si has been shown to control a number of diseases such as blast (*Magnaporthe grisea*) in St. Augustine grass, brown spot (*Cochliobolus miyabeanus* Ito and Kuribayashi in Ito Drechs ex Dastur) in rice and sheath blight (*Thanatephorus cucumeris* (A.B. Frank) Donk. in rice, and increase the tolerance of various turf grasses to *Rhizoctonia solani, Pythium* spp., *Pyricularia grisea* (Cooke) and *Blumeria graminis* (DC) (Carver *et al*., 1998; Savant *et al*., 1997; Alvarez and Datnoff, 2001; Seebold *et al*., 2000, 2004; Zhang *et al*., 2006). The mechanism by which Si confers disease suppression is not well understood. It is believed that Si creates a physical barrier which can restrict fungal hyphae penetration, or it may induce accumulation of antifungal compounds such as flavonoid and diterpenoid phytoalexins which can degrade fungal and bacterial cell walls (Alvarez and Datnoff, 2001; Brescht *et al*., 2004). Except from the essential nutrients for plant growth and development, there are a number of other elements that can occur in plant tissue in trace amounts (Li, Na, Be, Al, Ge, F, Br, I, Co, Cr, Cd, Pd and Hg) and have occasionally been linked with host-pathogen relationships. Li and Cd through their marked suppressive effects on powdery mildews are the most noteworthy. Cd was found to inhibit spore germination and development at a concentration of 3 mg kg^{-1}, which is not toxic but elicits a response to infection in the host. Cd and Hg can also promote synthesis of lignin in wheat (Graham and Webb, 1991). The mechanism of Li is not known and it is quite possible that it catalyzes a metabolic pathway which can function in defense.

5. Integrated nutrient management for diseases control

The mustard crop damaged by several diseases, including Alternaria blight, white rust downy mildew, Sclerotinia rot and powdery mildew which cause major loss to potential yield of seeds. Generally, 32 kg N, 16 kg P, 16 kg K and 16 kg S per acre is recommended for mustard (Satyagopal *et al*., 2014). Application of $CaSO_4$ @ 0.5 and 1.5% have reduced Alternaria leaf blight disease index *i.e*. 10.1% and 13.6%, respectively (Kumar *et al*., 2015). Similarly, Bhattacharyya and Mandal (2006) have reported control of clubroot of rapeseed-mustard by application of inorganic N fertilizers. It was reported that application of micronutrients into soil along with foliar spray of Rovral fungicide could inhibit Alternaria leaf blight infection in leafs upto 82.3% compared to control (Haider *et al*., 2014). The lower leaf removal of *Brassica* sp alongwith application of balanced nutrition is considerably effective in reduction of Alternaria blight (Meena *et al*., 2015). Studies have reported the effectiveness of garlic bulb extract in control of Alternaria blight (Meena *et al*., 2011, Meena *et al*., 2013). It was reported that seed treatment with *Trichoderma harzianum* @ 10 g/kg seed followed by foliar spray of Ridomil MZ 72 WP (metalaxyl 8% + mancozeb 64%) @ 2 g/L water after 50-60 days of sowing, significantly reduced the Alternaria leaf and pod blight up to 43.6 and 30.8%, respectively and white rust and stagheads up to 39.5 and 23.3%, respectively (Rathi and Singh, 2009). Hossain and Mian (2005) integrated the different management practices including soil treatment with sulphur-zinc-magnesium-molybdenum-boron (S-Zn-Mg-Mo-B) @ 30-5-1-1-1 kg/ha alongwith recommended (N-P-K) and spraying of fungicide Iprodione (0.2%) recorded a reduction of about (93.2%) in Alternaria blight disease. Powdery mildew and Scleritonia rot could be best reduced by treating seed with chemical followed by foliar spray of garlic bulb (Meena *et al.*, 2011). The diseases like Alternaria blight, white rust, Sclerotinia rot could be delayed or avoided by timely planting of the crop in most mustard-growing areas. Integrated cultural and chemical control of few diseases in Indian mustard (Table 9).

Soil amendments that raise the pH, such as lime and wood ash, may generate conditions that are unfavourable for clubroot infection and development. Such amendments are most effective where inoculum levels are quite low, and their use should be preceded by a soil test to conclude if treatment is agronomically advantageous. Lime amendments are exists in various forms, e.g. agricultural lime (calcium carbonate and calcitic lime), dolomitic lime (calcium and magnesium carbonate), hydrated lime (calcium hydroxide), and quicklime (calcium oxide). Repeated applications of lime may reduce the availability of nutrients, such as phosphorus, boron, magnesium, manganese and zinc (Howard *et al*., 2010).

6. Role of mustard varieties in tolerance of diseases

Use of resistant varieties to counteract diseases is one of the best environment friendly ways to avoid chemicals. Germplasm lines found tolerant to Alternaria blight in *B. juncea* are: PHR-2 PAB 9511, PAB 9534, EC 399301, EC399299, EC399313, RC 781 and JMM 915. Early dwarf high yielding mustard strain "DIVYA" possesses the growth and developmental traits associated with high degree of tolerance to Alternaria blight (Kolte *et al.*, 2000). Four varieties viz. NPC-9, Kiran, Pusa Karisma and RLM-619 were found resistant to Sclerotinia rot (Yadav *et al.*, 2011). Resistant/tolerant varieties of mustard against different diseases are given in Table 10.

Table 9: Describes cultural and chemical control for few diseases (Meena *et al*., 2014)

Disease name	Causative organism	Symptoms	Cultural control	Chemical control
Alternaria blight	*Alternaria brassicae*	· Leaves shows grayish to black necrotic spots · Infected pod produce shriveled seeds	· Use seeds of certified/ resistant/ tolerant variety · Adopt timely sowing between10-25 October · Follow proper field sanitation · Remove weeds particularly collateral host plants · Apply recommended dose of nutrients in soil to reduce disease incidence	Metalaxyl 8% + mancozeb 64% WP @1000 g in 400 L of water/acre
Powdery mildew	*Erysiphe cruciferarum*	Infected leaves produce white powdery mould on the top surface of leaves	· Follow timely sowing of seeds · Adopt proper field sanitation · Destruct crop infected crop residues · Apply recommended dose of nutrients in soil to reduce disease incidence	Triadimefon (Bayleton) 25 WP @1%
Sclerotinia rot	*Sclerotinia sclerotiorum*	Elongated lesions appear on stem later shows cottony growth	· Deep ploughing of field during summer · Crop rotation with non host crops like wheat, barley, rice, maize etc. · Sowing of healthy, certified and clean seeds free from the sclerotial bodies · Apply recommended dose of nutrients in soil to reduce disease incidence	FS (0.1%) seed treatment of *Tricho derma* (8 g/kg) and carbendazim (2g/kg), combinations of seed treatment (ST) and foliar spray of carbendazim, ST+FS *Trichoderma* and FS
White rust	*Albugo candida*	Small white raised rust pustules join together to form irregular large patches covering	· Use certified seeds of resistant/tolerant variety · Follow timely sowing of crop · Adopt proper field sanitation · Follow proper crop rotation · Destruct crop debris particularly stag heads of previous year crop · Apply recommended dose of nutrients in soil to reduce disease incidence	· Metalaxyl 35% WS @ 0.75- 1.0 kg/100 kg seed. · Metalaxyl M 4% + mancozeb 64% WP @ 1000 g in 400 L of water/acre · Metalaxyl 8% + mancozeb 64% WP @1000 g in 400 L of water/acre
Downy mildew	*Hyaloperonospora parasitica*	Creamy white to light brown spots with cottony growth indicates fungus	· Crop rotation · Remove infected material · Apply recommended dose of nutrients in soil to reduce disease incidence	· Seed dressing 640g/ kg mancozeb+ 80 g/ kg metalaxyl)
Club root	*Plasmodiophora brassicae*	Plants remain stunted. Leaves turn pale yellow. Club shaped out growth in roots	· Diseases can be reduced by raising pH · Liming is also beneficial · Drainage of the field should be properly managed · Apply recommended dose of nutrients in soil to reduce disease incidence	Calcium cyanamide (Perlka, 50% calcium oxide, 19.8 % nitro gen, 1.5 % magne sium oxide)

Table 10: Resistant/ tolerant varieties of rapeseed-mustard

Disease	Tolerant/resistant varieties
White rust	Pusa Karishma (LES-39), Jawahar Mustard-1, JM-2, PBR 91, Basanti, DMH-1, EC 399300, EC 399301, PWR 2001, PWR 9541JTC 1, Kiran (PBC-9921), Pusa Gaurav (DLSC 1), Pusa Swarnim (IGC 01), GSL-441, HNS-4, PBN-2001,PBN-2002
Alternaria blight	EC-129126, EC 399301, PAB 9511, PAB 9534, RC 781 PBC-9921 (Kiran), PC 5, Pusa Swarnim (IGC 01) GSL-1, HNS-3, PBN-9501, PBN-9502, PBN- 2001, PBN-2002

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