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Towards oilseeds sufficiency in north eastern hill region of India: Augmenting oilseed production in acid soils

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Abstract
Rapeseed and mustard contributes 32 per cent of the total oilseed production in India. It is the second largest oilseed group crop after groundnut. The North Eastern Hill (NEH) region of India is primarily under the acidic soil zone with high rainfall area. Oilseed crops are important for NEH region as oil is utilized thought the region for cooking and frying purposes. The oilseeds are extensively used as condiments in preparation of pickles, curries and vegetables. The leaves of young plants are also used as green vegetables as it supply enough sulphur and minerals in the diet. However, oilseed cultivation in the NEH region faces several constrains, such as soil acidity problem, water scarcity during post-monsoon season, lack of irrigation facilities, short time lag after rice harvest for seed sowing and lack of soil test based fertilizer recommendations. As a result, only mono-cropping of rice is practiced and the farmers leave their land fallow during *rabi* season. Considering oilseed Brassica as important oilseed crops for NEH region due to its lower water requirement and tolerance nature to acidity, rapeseed (*Brassica campestris* var. *toria*) after harvest of rice was introduced at farmers' field under zero tillage conditions. Among tested rapeseed varieties, TS-38 gave maximum average yield of 790 kg ha^{-1} under moisture stress conditions in acid soils. For getting optimum production of oil seed crops in acidic soils, the critical limits of available phosphorus for rapeseed (*Brassica campestris* var. *toria*) were also quantified and communicated to the farmers. Apart from this, several other investigations were carried out on different oilseed crops to augment oilseed production in acid soils of the region. The concentrated efforts indicated that rapeseed is a climate resilient crop which can be grown in the residual soil moisture and the farmers of NEH region can meet out their nutritional need and secure livelihood through increased oilseed productivity and reduced cost of cultivation.

Keywords: oilseeds, rapeseed, north-eastern hill region, acid soils, zero tillage, phosphorus

Introduction
Oilseed is the second most important crop group which determines agricultural economy, next to cereals. India is world's fourth largest edible oil economy after the U.S., China and Brazil. Globally, it contributes almost 6 per cent of global vegetable oil production, 14 percent of vegetable oil imports and 10 per cent of edible oils (Mir *et al.*, 2010). Rapeseed and mustard contributes 32 per cent of the total oilseed production in India and it is the second largest oilseed group crop after groundnut. It contributes to the 4.1 M ha area and 6.6 Mt production of total oilseed and mustard of India with average productivity of 1182 kg ha^{-1}. Oil seed crops are important for the North Eastern Hill (NEH) region of India as oil is utilized throughout the region for cooking and frying purposes. The oil seeds are extensively used as condiments in preparation of pickles, curries and vegetables. The leaves of young plants are also used as green vegetables as it supply enough sulphur (S) and minerals in the diet. However, the per capita availability of oilseed in the region is 8 g day^{-1} as against moderate requirement of 50 g day^{-1}.

The NEH region of India is primarily under the acidic soil zone with high rain fall area. Approximately, 84 per cent of the soils in the NEH region are acidic in reaction, having low available phosphorus and zinc whereas toxicity of iron and aluminum (Sharma *et al.*, 2006) [10]. In acid soils, P adsorption is generally attributed to hydrous oxides of iron and aluminium. There is great possibility that some natural phosphates of aluminium or iron (such as variscite and strengite) may formed in these soils. Therefore, P is the most limiting nutrient for crop production in acid soil. Moreover, majority of the fields in the region are situated across the hilly slopes with shallow and gravely soils. Shifting cultivation (*Jhum*) is one of the predominant agriculture practiced by the tribal inhabitants. Utilization and improvement of soil resources is of paramount importance for enhancing crop production. The population growth in this region is rapid and food demands are speedily increasing but large chunk of the area is under fallow after the rainy season crop. This pressurizing the growers to produce more food per unit area, in phosphorus (P) deficient acid soils (Choudhary *et al.*, 2013) [1].

Apart from soil acidity problem, oilseed cultivation in the NEH region faces several other constrains, such as water scarcity during post-monsoon season, lack of irrigation facilities, short time lag after rice harvest for seed sowing and lack of soil test based fertilizer recommendations. It was realized that rice-fallow cropping system may be substituted by introducing short duration oilseed crops like toria (*Brassica campestris* var. toria) along with other possible measures with the hope that toria will not only provide additional yield coupled with better land use efficiency but also will help the resource poor the traibal farmers of the region in improving the livelihood and nutritional security.

Materials and Methods

The production of oilseeds under acidic soils of North East Hill region can be augmented by adopting the modern crop production techniques and sustainable use of available natural resources, use of chemical fertilizers to supply essential plant nutrients in required amount and in available form which increase the uptake of nutrient under acidic soils of hilly region. Therefore, rapeseed (*Brassica campestris* var. *toria*) was introduced after harvest of rice at farmers' field under zero tillage conditions and the critical limits of available phosphorus in acid soils for rapeseed were also quantified and communicated to the farmers. Some other crop production techniques were also refined such as lime application, mulching, green manuring, and pollination techniques for augmenting oilseeds production in the region.

Results and Discussion

(i) Adoption of zero tillage practice

Water scarcity during post-monsoon seasons and lack of irrigation facilities, short time lag after rice harvest for seed sowing and high incidence of pests and diseases in late sown crops are the major constraints for oilseed cultivation in the NEH region. As a result, only mono-cropping of rice is practiced and the farmers left their land fallow. The Central Agricultural University, Imphal in collaboration with Directorate of Rapeseed-Mustard Research, Bharatpur implemented an extension project entitled, "Augmenting rapeseed-mustard production of tribal farmers of North Eastern states for sustainable livelihood security" under the Tribal Sub-Plan (TSP) during *rabi*, 2011. Yield performance of rapeseed varieties, M-27 and TS-36, Yellow Sarson, Ragini, and mustard varieties, Pusa Agrani, Pusa Mahak, NRCHB-101 and NPJ-112 were evaluated in 55 ha under zero tillage cultivation and compared with crops grown in 40 ha under conventional tillage (Plate 1 & 2).

Besides, no tillage (zero tillage) practice, use of 4 (four) bee colonies ha^{-1} during crop bloom for pollination and spray of botanical pesticides without affecting pollinators population and production of organic honey, were demonstrated. Since there was no rain throughout the crop period, the growth and yield parameters in all the rapeseed-mustard varieties were better in zero tillage than conventional tillage due to residual soil moisture after rice harvest. Among the rapeseed varieties, Yellow Sarson, Ragini gave the maximum average yield of 1000 kg ha^{-1} (range: 800 to 1400 kg ha^{-1}), whereas, NRCHB-101 among mustard varieties gave maximum average yield of 1020 kg ha^{-1} (range: 800 to 1100 kg ha^{-1}) both in zero tillage cultivation. In all, 172 farmers across 9 (nine) villages of Imphal East District involved in the project improved their income by getting average net profit of Rs.27,388 ha^{-1} including cost of honey within three and half months with a low investment of Rs.13,412 ha^{-1}. By observing the standing crop in the fields, altogether 1419 farmers across 50 villages in 10 (ten) districts of 3 (three) North Eastern states namely, Manipur, Mizoram and Arunachal Pradesh adopted this technology and the area coverage under zero tillage cultivation of rapeseed-mustard increased to 1010 ha during *rabi*, 2012 and 2013.

Under the water stress situation where there was no rainfall during the crop period of *rabi* 2012, M-27 among rapeseed varieties and YSH-401 among Yellow Sarson varieties and NRCHB-101 among mustard varieties gave maximum average yield of 600, 1000 and 1190 kg ha^{-1}, respectively under zero tillage cultivation. Similarly during *rabi* 2013 under the water stress situation, TS-38 among rapeseed varieties, YSH-401 among Yellow Sarson varieties and NRCHB-101 among mustard varieties gave average yield of 790, 950 and 1180 kg ha^{-1}, respectively under zero tillage cultivation. It indicated that rapeseed-mustard is a climate resilient crop which can be grown without water in the residual soil moisture. By adopting zero tillage, the farmers can increase the productivity, reduced cost of cultivation thereby increasing the cropping intensity and earning an additional income for themselves with less efforts (Plate 1). Zero tillage also helped in timely sowing (October-November), conserved soil moisture and required less water, saved tillage cost and time, and the soil was protected from erosion due to the retention of surface residues and reduced organic matter depletion.

Plate 1 & 2: Zero tillage cultivation of rapeseed, TS-38

Plate 3: Training programme on zero tillage cultivation of rapeseed

The improved version of this zero tillage cultivation with bee pollination and no chemical method of plant protection may be recommended to the resource poor farmers of the North Eastern Hill region in the context of climate change.

(ii) Managing phosphorus availability in acid soils

For managing phosphorus availability in acid soils, the right P doses were quantified to get optimum production of oil seed crops. Sanjay-Swami and Maurya (2018) [9] determined critical limits of available phosphorus for rapeseed (*Brassica campestris* var. *toria*) in acid soils of NEH region. The investigation was carried out during *rabi* season of 2016-17 using 6 levels of P (0, 30, 60, 90, 120 and 150 mg kg^{-1} soil) applied through two sources *viz.* single super phosphate (SSP) and rock phosphate (RP) in different acidic soils *viz.* Alfisol and Inceptisol.

It was observed that the highest mean dry matter yield of rapeseed (16.11 g pot^{-1}) was recorded with the application of 120 mg of P kg^{-1} of soil (Table 1). The further increase in the dose of P by 150 mg of P kg^{-1} soil significantly decreased the dry matter yield by 4.59 per cent over 120 mg of P kg^{-1}. The dry matter yield produced with RP was of lower order as compared to SSP at each levels of P irrespective of soil type. The Inceptisol has produced significant higher amount of dry matter as compared to Alfisol irrespective of P sources. The highest dry matter yield (17.81 g pot^{-1}) was observed in Inceptisol with 120 mg kg^{-1} soil under SSP, whereas the lowest dry matter yield (5.57 g pot^{-1}) was recorded in Alfisol with control under RP. Similarly, significant difference in dry matter yield of rapeseed was found between the two sources of P irrespective of the soil type. In Alfisol, the SSP has produced 7.71 per cent higher dry matter yield over RP in control whereas, in Inceptisol SSP has produced 2.56 per cent higher dry matter yield in control pots.

Table 1: Effect of different levels and sources of P on rapeseed dry matter production in acid soils of North East India

P levels mg kg^{-1} soil	Alfisol		Inceptisol		Mean
	RP	SSP	RP	SSP	
0	5.57	6.00	7.02	7.20	6.45
30	9.34	10.30	10.77	11.89	10.58
60	12.12	13.20	14.14	15.61	13.77
90	14.21	15.00	16.13	17.68	15.76
120	14.44	15.20	17.02	17.81	16.11
150	14.12	14.90	15.80	16.65	15.37
RP	12.56	Alfisol	12.03	S.E(m)±	0.14
SSP	13.45	Inceptisol	13.98	CD (p=0.05)	0.39
For Source of P and Soils		Interaction			
		S x So	S x L	So x P	S x So x L
S.E(m)±	0.08	0.11	0.19	0.19	0.28
CD (p=0.05)	0.23	0.32	0.55	0.55	0.78

Further, it was also found that the application of P with different levels significantly improved the P uptake by rapeseed plants. The overall mean P uptake in the control was recorded to be 9.83 mg P pot^{-1} in control, which increased significantly by 4.9 times with the application of 120 mg P kg^{-1} soil (Table 2). The P uptake by rapeseed plant showed an increasing trend from no P application to the 120 mg P kg^{-1} soil in Inceptisol and thereafter it reduced whereas in Alfisol, the P uptake increased up to 150 mg P kg^{-1} soil. The highest P uptake was recorded in Inceptisol through SSP as a source i.e. 59.37 mg pot^{-1} compared to RP (49.52 mg pot^{-1}) whereas in case of Alfisol, highest value of P uptake was recorded through SSP (45.23 mg pot^{-1}) compared to RP (39.06 mg pot^{-1}).

Table 2: Effect of phosphorus sources and levels on P uptake (mg pot^{-1}) of rapeseed in acid soils of North East India

P levels mg kg^{-1} soil	Alfisol		Inceptisol		Mean
	RP	SSP	RP	SSP	
0	6.88	8.63	11.04	12.78	9.83
30	13.35	17.85	22.95	27.84	20.50
60	21.81	26.85	34.92	42.25	31.46
90	33.65	37.91	44.70	54.83	42.77
120	38.96	43.62	50.51	59.37	48.12
150	39.06	45.23	49.52	58.25	48.01
RP	30.61	Alfisol	27.82	S.E(m)±	1.16
SSP	36.28	Inceptisol	39.08	CD (p=0.05)	3.30
For Source of P and Soils		Interaction			
		S x So	S x L	So x P	S x So x L
S.E(m)±	0.67	0.95	1.64	1.64	2.32
CD (p=0.05)	1.91	2.69	4.67	4.67	6.60

The critical limit of available P were established by Bray P_1 soil test method for rapeseed (cv. M-27) as 38.5 kg P ha^{-1} under RP and 31.0 kg ha^{-1} under SSP in Alfisol, whereas in Inceptisol, the critical limits of available P were established as 37.0 kg P ha^{-1} under RP and 29.5 kg P ha^{-1} under SSP.

(iii) Lime application

Use of lime is often recommended to increase the crop productivity in acidic soils. To ascertain the individual and synergistic effects of lime, NPK and farm yard manure (FYM) application on ground nut productivity, a field experiment was undertaken on acid soils of West Tripura. Application of recommended dose of NPK (20:60:42 kg ha^{-1} of NPK) along with lime (10 per cent of actual LR was followed) resulted in 153 per cent yield increase over control whereas, FYM @ 5 t ha^{-1} along with combined application of lime with recommended NPK boosted the yield improvement up to 210 per cent over control i.e. farmers' practice (Table 3). Results of this study suggested that liming along with integrated nutrient management practices, if adopted properly, can lead to more than two-fold increase in ground nut productivity on acidic soils of West Tripura and other districts of Tripura with similar soils. Post harvest soil analysis also showed improved status of organic C, N and P in treated plots, but available K status declined emphasising the need for close monitoring and appropriate K application in such soils (Dey and Nath, 2015) [2].

Pod yield was significantly increased with addition of sole lime and combined application of lime and FYM along with RDF. These results are confirmatory of the previous findings of Sharma *et al.* (2006) [10] who, based on 141 experiments in field across the Assam and Meghalaya reported 14-50 per cent increase in yield of crops in response to lime application @ 200-400 kg ha^{-1}, 22-100 per cent yield increase by recommended dose of NPK application i.e. 100 per cent NPK, and 49-390 per cent higher yield with combined use of NPK and lime compared to control i.e. farmers' practice. This might be related to the issue of balanced nutrition of crops that goes beyond the context of N, P, and K. Farmyard manure not only supplied nutrients but also improved soil conditions to produce higher yields. FYM might have stimulated the activities of micro-organisms that make the plant nutrients readily available to the crops. Use of microbial inoculants in combination with FYM favoured groundnut production.

Table 3: Effect of liming on kernel yield of groundnut under acidic soils of West Tripura

Treatments	Pod yield (kg ha^{-1})
Lime (10 % of actual LR) + RD of NPK	1130
Lime (10 % of actual LR) + RD of NPK + FYM 5 t ha^{-1}	1728
Farmer's practice	2373

(iv) Mulching

Use of various mulches is also important factor because under hilly conditions soil water is the major constraints. Although, weeds are the universal problem in agriculture, but under upland condition and high rainfall areas, weeds create more problem. Use of green manuring techniques and also liming practices help in reduction of iron toxicity to oilseed crops under acidic condition. The effects of mulching on soil moisture depend on precipitation and climatic factors. Mulching favourably influences soil moisture regime by controlling surface evaporation rate in summer and winter, mulching conserves soil moisture by reducing the evaporation rate. Mulches improve soil-moisture retention capacity as well as soil structure and suppress weed growth (Mutetwa and Mtaita, 2014) [5]. The soil-moisture variation is not, however, same under different mulching materials. The amount of soil-moisture conservation under different mulching materials differs in different soil types and climatic conditions. In general, the mulching treatments store higher soil moisture compared to the bare soil (no mulch) (Zhao *et al*., 2012) [12].

Application of organic mulches decreases the soil temperature as it creates barrier for penetration of solar radiation to soil surface. Paddy straw is easily available in NEH region during November-December and it is an eco-friendly source of organic mulch. It is cheap and benign technology for rural farmers. It also conserves soil moisture, maintaining favourable soil moisture regimes by reducing evaporation loss from soil. Rice is a core cash crop and staple food in many Asian countries (Rao *et al*., 2007; Kumar and Ladha, 2011) [7, 3]. The biological and chemical properties of soils play an essential role for the regulation of organic matter decomposition, carbon sequestration and nutrient mineralization that are crucial for soil health which leads to increased oilseed production.

(v) Green manuring

Green manuring play important role in supplying nutrients for crops, improving ecological environments of agricultural fields, reducing soil erosion and pollution, restraining global warming potentials, and contributes to higher crop yields. Green manures can be fitted into rice farming systems in either the pre-rice or post rice phase. Planting of winter green manures after the late rice has been proved to be an effective rotation pattern in improving soil conditions, soil fertility and rice yields. Many studies reported that the application of green manures changed the chemical and biological characteristics of soils. Milk-vetch (*Astragalus sinicus* L.), one kind of winter-growing legumes, has been widely used as green manure in rice fields to fertilize the soils in Japan and China (Samarajeewa *et al.*, 2005) [8], and as an alternative N source for chemical fertilizer in double-rice cropping systems. Rape and ryegrass are also commonly used as green manures, and have the potential to improve sustainable production of double cropping rice.

(vi) Pollination techniques

Planned crop pollination is considered to be the most important input as all other inputs will be just useless if pollination does not occur. Because of yield optimizing benefits, bee pollination can play an important role in maintaining a sustainable and profitable agriculture with minimum environmental disruptions (Singh and Choudhary, 2005) [11]. According to Nagpal *et al.*, 2017 [6], the effect of different modes of pollination on yield parameters of Indian mustard showed that the maximum number of pods $plant^{-1}$, pod length, pod setting (%), number of seeds pod^{-1}, thousand seed weight, seed yield $plot^{-1}$, seed germination (%), seed vigour and oil content (508.72 pods $plant^{-1}$, 5.69 cm, 86.32%, 15.66 seeds pod^{-1}, 6.87 g, 1763.0 kg ha^{-1}, 89.20%, 628.12 and 39.42%, respectively) were in open pollination followed by that in bee pollination (404.56 pods $plant^{-1}$, 4.92 cm, 78.33%, 14.26 seeds pod^{-1}, 6.39 g, 1557.0 kg ha^{-1}, 85.20%, 542.54 and 38.36%, respectively) and pollinators' exclusion (287.56 pods $plant^{-1}$, 3.89 cm, 65.87%, 12.24 seeds pod^{-1}, 5.30 g, 1301.0 kg ha^{-1}, 78.40%, 385.54 and 37.04%, respectively). Seed yield increased by 35.50 and 19.66 per cent in open pollinated and *Apis mellifera* pollinated plots, respectively as compared to pollinators' exclusion (Table 4).

Table 4: Influence of mode of pollination in *Brassica juncea* flowers on yield and oil content

Treatments	Seed yield	Oil content (%)
Bee Pollination	15.57±0.22	38.36
Open Pollination	17.63±0.28	39.42
Pollinator's exclusion	13.01±0.35	37.04
SEm (±)	0.31	0.05
CD (p=0.05)	1.04	0.18

Conclusion

Oilseed cultivation in the NEH region faces several constrains, such as water scarcity during post-monsoon season, lack of irrigation facilities, short time lag after rice harvest for seed sowing and lack of soil test based fertilizer recommendations. As a result, only mono-cropping of rice is practiced and the farmers leave their land fallow after *kharif* season. Considering oilseed Brassica as important oilseed crops for NEH region due to its lower water requirement and tolerance nature to acidity, rapeseed (*Brassica campestris* var. *toria*) after harvest of rice was introduced under zero tillage conditions. The production of oilseed under acidic soils of NEH region can be augmented by adopting certain modern agro-techniques like adoption of zero tillage practice, managing phosphorus availability in acid soils by quantifying location specific right P doses, application of lime, mulching, green manuring and planned crop pollination technique, etc. Thus, all the above techniques are recommended for the farmers of North Eastern Hill region of India for augmenting oilseed production and livelihood security.

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