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CAN HIGH YIELDING VARIETIES PERFORM SIMILARLY IN ORGANIC FARMS?

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Abstract

With rise in demand of organic products because of health benefits and environment concerns, it becomes necessary to produce sufficiently, but unfortunately due to poor productivity, it is currently not possible to fulfil the future nutritional demand. The reason behind is using the same plant cultivar for both intensive and organic farming system and expecting a similar outcome. The major difference lies between the nutrient availability pattern and form in both the cases. The plants suitable for intensive (conventional) farming get high amount of nutrients at its peak stage whereas in organic farming, the manure applied needed to be decomposed first by microorganisms and follow mineralization process on which conversion to available form like NO_3^- and NH_4^+, hence its availability was low when it was highly required. Considering the mentioned problem it is highly desirable to breed the plants for organic conditions such that it can change the plants' nutrients absorption pattern, increase nutrient absorption capacity, reduced root losses due to pathogens, ability to maintain a high mineralization activity in the rhizosphere via root exudates, increased rooting depth and associated ability to recover N leached from the topsoil. A considerable approach is urgently required to sustain the rising organic food requirement.

Key words : Organic farming, breeding, high yielding varieties, conventional farming, nitrogen.

Introduction

The major challenge of organic farming is to maintain high yields and excellent quality utilizing farming practices that have acceptable environmental impacts (Tilman *et al*., 2002). The demand for organic food is steadily increasing both in developed and developing countries with annual growth rate of 20-25% (Ramesh *et al*., 2005). The problem lies with the productivity in the organic farm, which is giving low yield compared to conventional farming (farming with high inputs). Also according to an estimate the rising population will result in 9 billion populations at the end of the year 2050 with double the food demand as it is now (Tilman *et al*., 2002). This raises questions whether low organic yield can sustain the growing food demand? Or can high yielding varieties perform similarly in organic farms?

Several yield trial comparisons between organic and intensive farming system have shown significantly lower yield for organic system (Stanhill, 1990; Ryan *et al*., 2004; Seufert *et al*., 2012). A comparative study of different crops in the certified organic farms and their productivity levels to conventional farms are given in fig. 1. Since, the demand for organic food is rising, thus, to fulfil the growing demand high productivity is a need in organic farming. Around the world the crop grown since decades under the organic farming is mainly dependent on the crops bred based on high input sector and that didn't possess the required important traits needed under organic farming and low input sector (Lammerts van Bueren *et al*., 2002; Murphy *et al*., 2002; Wolfie *et al*., 2008). According to estimation, it almost covers 95 per cent of the total organically cropped area (Lammerts van Bueren *et al*., 2011). It means a huge area cultivated under organic farming needed to be standardized for better productivity by cultivating suitable variety. As said organic farming is devoted to naturalness of its culture which includes non-chemical, the agro-ecological and integrity approach which can be fulfilled if the crops fulfil their nutrient requirement sufficiently in an organic field at all stages of growth. Since crop bred for intensive agriculture are selected for

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high input sector and does not yield similarly in organic farming it is required to breed the variety, which is suitable for the organic farm.

Why organic farming?

Organic farming has been shown to improve many different environmental and human components of the agro-ecosystem (Reganold *et al*., 2001). A review of over 300 published reported (Stolze *et al*., 2000) showed that out of 18 environmental impact indicators (floral diversity, faunal diversity, habitat diversity, landscape, soil organic matter, soil biological activity, soil structure, soil erosion, nitrate leaching, pesticide residues, CO_2, N_2O, CH_4, NH_3, nutrient use, water use and energy use), organic farming performed significantly better in 12 and performed worse in none. There are also high pre-consumer human health costs to conventional agriculture, especially use of pesticides (Conwat and Pretty, 1991). Due to such rise in health consciousness and betterment of environment, a huge scope can be seen for the future. Currently cultivated organic agriculture varies from 0.00001% to 35.6% (Anonymous, 2013) where India falls in category of 0.49-3% and it is increasing year by year.

Nitrogen as a key factor

The plants responses by the action of their growth based on factors like the nutrient availability, form of nutrient available and the rate of nutrient turnover. The greatest difference between organic and intensive system relates to soil management practices used and to processes in the rhizosphere (Baresel *et al*., 2008). Both the factors are responsible for uptake of the nutrients from the soil. Among which nitrogen is the most limiting factor in organic farming (Madar *et al*., 2011) as breeding for intensive fertilizer regimes with abundant N may have resulted in varieties that are dependent on readily and consistently available N (Foulkes *et al*., 1998). When, we consider organic farming, it is evident that N availability depends on mineralization of crop residues and farm yard manures applied on the farm. In early crop growth stages when demand is low, N is lost while in later stages the demand from the plant is often much greater than the supply from mineralization. Matching N need and mineralization is indeed one of the major limiting factors in organic agriculture system (Pang *et al*., 2002). In other words, for intensive farming high nitrogen application with high yielding varieties gives higher yield (Godfray *et al*., 2010), which is not the case of organic farming. Taking the case of white cabbage with overall treatments with mineral N and for overall treatment with compost application, shows a rise in N uptake and increase in dry weight content when mineral N is applied, but the

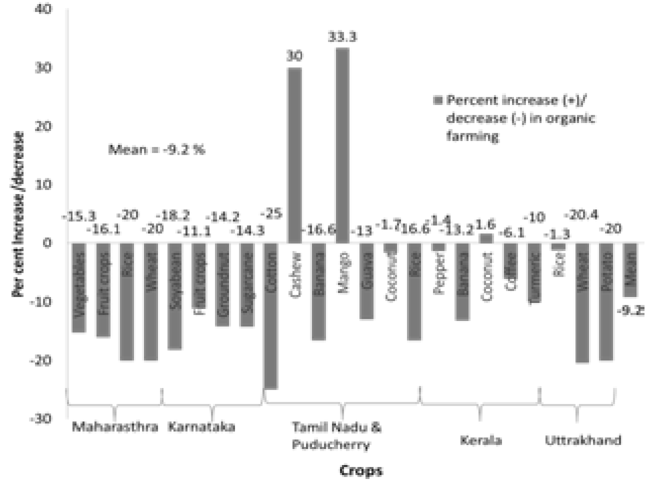

Fig. 1 : Productivity of crops (t/ha) in organic versus conventional farming (Ramesh *et al*., 2010).

same is not true for compost application as shown in the fig. 2.

The difference lies in the form of nutrient available to plant, *i.e.* in the soil N is available in many forms like easily soluble nitrate (NO_3^-), ammonium (NH_4^+) and to a lesser extent as proteins, peptides or amino acids (Good *et al*., 2004; Rentsch *et al*., 2007). Among these the available organic nitrogen fraction typically comprises 0.1% to 0.5% of the total soil N (Barbar, 1984) even though the actual pool size of organic forms of N can be large in agricultural soils (Mengel, 1996; Matsumoto, 2000). Soil microbes secrete proteases into the soil which facilitate the breakdown of nitrogen source like proteins and peptides into their constituent amino acid units (Owen and Jones, 2001). A range of amino acid transporters have been identified in roots of some plants (Fischer *et al*., 1998) and similarly some more dissolved organic N constitute the soluble N pool in soil, and plant root have potential to access some of this pool (Jones *et al*., 2005). These amino acids on mineralization release NH_4^+ and then converted to NO_3^-. A simple systematic diagram is given in the fig. 3. Thus, in other words it can be stated that for organic farming nitrogen is available but in different forms, but only a few can be absorbed by it and other are converted and then it might be possible to absorb. If crops cultivated can take amino acids by their transporters as discussed by Salisbury (1992), nitrogen may get more readily available to organically grown plants.

Environment and genotype

Plant response to its growth is influenced by both genotype and the environment (Salisbury *et al*., 1992). Inference is drawn from occurrence of interaction of genotype and N level, which indicate that the best promising varieties at high N fertilization are not

Table 1 : General criteria for variety characteristics desired for organic farming systems derived from the agro-ecological approach (After Lammerts van Bueren *et al*., 2002).

Variety characteristic	**Criteria**
Adaptation to organic soil fertility Management	• Adapted to low(er) and organic inputs; able to cope with fluctuating nitrogen dynamics (growth stability); • Efficient in capturing water and nutrients; deep, extensive root system; • Able to interact with beneficial soil micro-organisms, like mycorrhizae and atmospheric nitrogen-fixing bacteria; • Efficient nutrient uptake, high nutrient use efficiency.
Weed suppressiveness	• Plant architecture for early soil cover and more light competition; • Allelo-chemical ability; • Allowing and resisting mechanical weed control.
Crop health	• Mono- and poly-factorial, durable resistance; • Field tolerance; • Plant morphology; • Combining ability for crop and variety mixtures; • Capable of interaction with beneficial microorganisms that enhance plant growth and suppress disease susceptibility.
Seed health	• Resistant or tolerant against diseases during seed production, including seed-borne diseases; • High germination percentage; • High germination rate; • High seedling vigour.
Crop quality	• Early maturing; high processing (baking) quality; • Good taste; • High storage potential.
Yield and yield stability	• Maximum yield level and yield stability under low-input conditions.

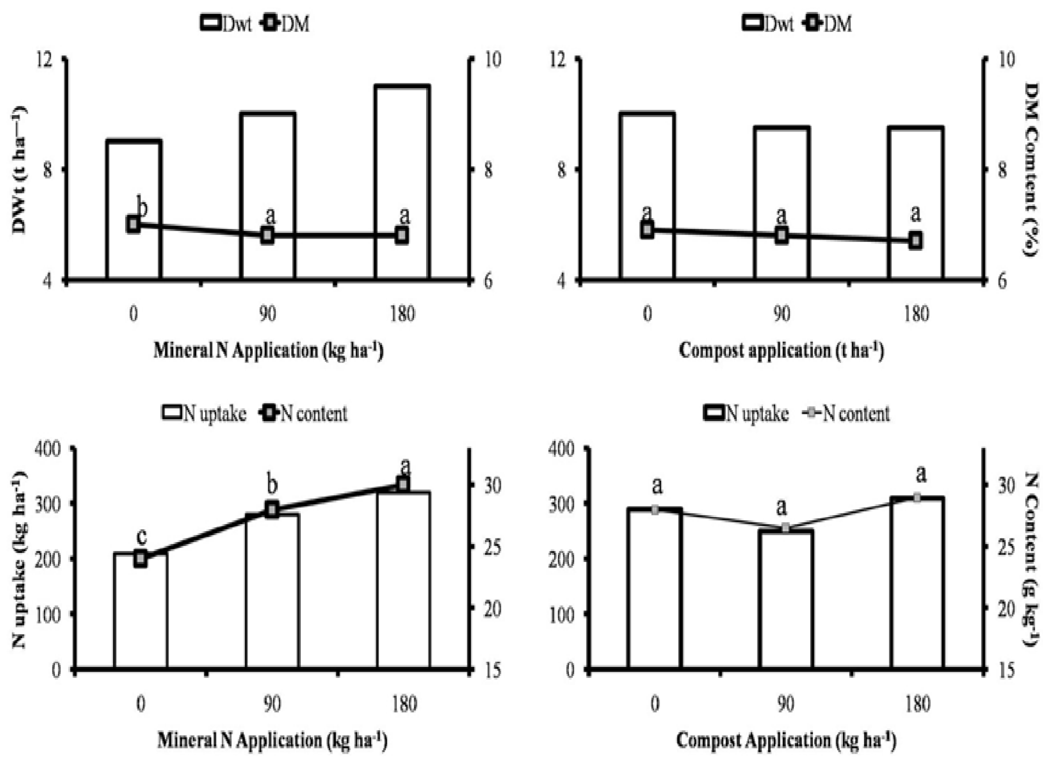

Fig. 2 : White cabbage dry weight (DWt), dry matter (DM) content (%), N uptake (kg ha^{-1}) and N content (g kg^{-1}) for the overall treatments with mineral N and for the overall treatments with compost application. Different letters above bars mean significant differences in cabbage DWt or N uptake (Brito *et al*., 2012).

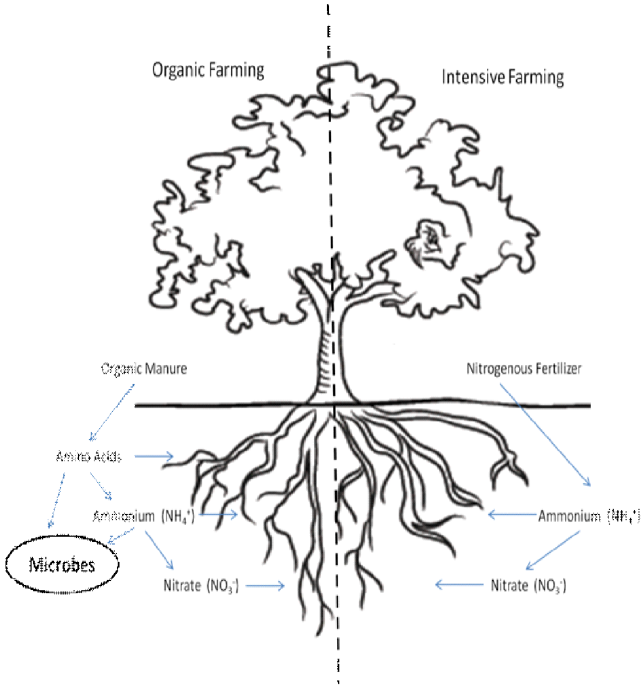

Fig. 3 : Organic farming VS Intensive farming.

Table 2 : Current breeding programs in different countries.

Country	Institute/ Company	Crop	Remarks
Austria	SaatzuchtDonau GmbH & CoKG (Private)	Wheat	• 16 varieties released. • Found crops grown under organic condition have better baking quality.
France	INRA (Public)	Wheat	• Proposed a global selection index that takes into account yield, quality and weed competition to optimize yield.
Switzerland	GZPK (Private)	Wheat	• 10 varieties released
USA	Washington State University	Wheat	• Highest yielding genotypes in conventional systems are not the highest yielder in organic system. • Direct selection of varieties gives 5-31 % higher yield than the yields resulting from indirect system
USA	Oregon State University	Tomato	• Varieties released which are also resistance to late blight (Loschenberger *et al*., 2008; Kempf, 2002; Goyer *et al*., 2005; Rolland *et al*., 2008; Behrendt, 2009)

necessarily the best ones where the supply of N is lower (Gallois and Coque, 2005). Thus breeding crops specifically for organic system is gaining attention as farmers and researchers realize that beneficial traits for these systems may be very different from produce high yield in conventional agriculture (Murphy *et al*., 2007), for example, genotypic differences were reported in wheat cultivars for the capacity to the up-take amino acids and this may certainly affect their performance in organic farming system (Reeve *et al*., 2009). Since N is the most limiting factor, high nitrogen uptake and nitrogen use efficiency can be the objective for organic agriculture (Hirel *et al*., 2011).

The current modern varieties are adapted to conventional agriculture that has put in a lot of effort to minimize or simply overrule diversity in the cultivation environment, and breeding has mainly been focused on such relatively standardized farming systems (Jongerden and Ruivenkamp, 1996). This makes the modern varieties adapted to high input sector. Thus, suitability of the same variety in both the condition cannot give similar result. Improving the different components of nutrient-use efficiency, like maintenance of photosynthesis under nutrient stress, nutrient uptake capacity, nutrient-utilization capacity and translocation efficiency, will contribute to higher yield and quality under low input conditions. For organic farming, the adaptation of varieties to efficient nutrient-use derived from slow-nutrient-releasing organic fertilizer is of special importance, which is not addressed in conventional selection programmes with no or less inorganic fertilizer (Dawson *et al*., 2008).

It is quite true to say that at present conventional farming is more productive, not only with the sense that it gives higher yield but it also includes environmental factors based on the other cultural practices that are not similarly or equally followed in organic farming (Lammerts van Bueren *et al*., 2002). Cultural practices like weeding, pesticide application, crop health, seed health directly or indirectly alters the yield parameter. To overcome each of the parameter we are using one or the other chemical under conventional farming but condition is not same for the organic farming.

Taking care of this parameter it is quite desirable to select the plants, which acts equally or better to sustain such parameters and ultimately help to increase the yield. The criteria needed for a desired organic farming are mentioned in the table 1.

Current breeding programmes running in different countries

The concept of breeding uniquely for organic farming is quite recent and many agencies in many nations are engaged to solve the demerits of organic farming especially the crop productivity. Few of them are mentioned in the table 2.

Constraints of breeding for organic farming

Organic farming is a good option over intensive farming by getting good varieties for the same. To breed a good variety the major constraint lays is the land availability, budget allocation or land managed to organic farming standards (Lammerts van Bueren *et al*., 2011). Moreover, the time needed to select a desirable trait is huge. Due to this participation of private agencies are poor and research in public sector is also not very much encouraging.

With advancement of molecular biology and biotechnology, the search to identifying genes that regulate nitrogen use efficiency of crop plant made progress and successfully transgenic traits have developed (McAllister *et al*., 2012). However, transgenic approach is associated with problem of expression and nitrogen use efficiency phenotype development and these approaches also conflicted with the core concept of organic agriculture where integrity of plant material is maintained (Lammerts van Bueren *et al*., 2003). Thus, transgenic crop is not the solution for organic farming.

Conclusion

Organic farming is the need of the future and with rising demand day by day, it become mandatory to improve both its stability and productivity. Since the response for a current plant type sin organic and intensive farming is different, so there is a need that breeding program for organic farming to be carried out separately. Moreover, the variety released for organic should not only be for high yielding but also have characters that enable the plant to overcome problem such as weed, pest, diseases, seed germination, plant health, root architecture etc. as the plant performance is not only genetic but also affected by environment and management practices (Genotype × environment × management practices), which ultimately alters and hence needed to be taken care of.

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