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A REVIEW

Integrated nutrient management in maize

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The literature on integrated nutrient management in maize crop has been well documented. In this article efforts have been made to review the literature available on integrated nutrient management in corn. The effect of integrated nutrient management on growth character, yield attributes, yield, nutrients uptake, quality characters and economics were presented here. Today, for the country of India's dimension, with no scope for horizontal expansion and complexity of problems and challenges, there is no alternative but continue to improve productivity without further degrading its natural resources that too in a sustainable manner (Narayanswamy *et al.*, 1994). In this contest we will have to adopt a rationalist organic farming approach to have an 'Evergreen Revolution'. This has led to the concept of integrated nutrient management (INM) gain momentum in recent years to improve and maintain the soil health. Besides this, with escalating cost of energy based fertilizer material, limited fossil fuels, INM approach combines the use of organic sources along with fertilizers, which would be remunerative for getting higher yields with considerable fertilizer economy (Subbian and Palaniappan, 1992).

It is well documented that integration of organic and inorganic nutrient sources is the only possible way to maintain the soil health and meet the total crop nutrient demand in a sustainable way. Organic nutrient sources are known to restore soil physical environment and enhance nutrient use efficiency by a crop, in such a way that they influence growth, yield and quality of a crop.

The research work done in India and elsewhere in recent years on the effect of organic and inorganic sources of nutrients on growth and yield of sweet corn and potato related crops are reviewed in this chapter. The literature collected on these aspects have been presented under the following subheads.

Growth character, yield attributes and yield:

The organic manures are important agricultural by-products which are regarded as a great value by cultivators and gardeners since organic materials are used to maintain or improve the tilth, fertility and productivity of agricultural soil.

There is no doubt that the application of chemical fertilizers on crop can lead to increase in crop productivity but continuous application of it can pose deleterious effect to soil health as well as loss of some of beneficial micro

nutrients and leaving some residual effect to the crop harvest thereby affecting human health too.

The nutrient supply is a key factor in crop production, but the global crisis of energy and high cost of fertilizer nutrients enforced to economize their use by applying organic sources and chemical fertilizer together.

Chandrashekara *et al.* (2000) conducted the field experiment in Arabhavi, Karnataka during the *Kharif* season of 1996 and reported that the application of poultry manure (10 t ha^{-1}) with recommended rate of fertilizers (RRF 150 kg Nha^{-1} in three split doses) produced taller plants (187.5 cm) longer cobs (14.35 cm) with bigger diameter (15.6 cm) and heavier cob weight (170.5 $gcob^{-1}$) than application with control. The per cent increase in cob length, cob girth and grain weight per plant with the application of poultry manures was 13.1, 23.8 and 53.2 per cent, respectively, compared with control.

Nanjappa *et al.* (2001) conducted an experiment on maize to study effect of integrated nutrient management at Bangalore, Karnataka. The grains per row were recorded maximum with 75% RDF + FYM 6 t ha^{-1}, which was at par with RDF (150 : 75 : 40 kg NPK ha^{-1}) alone and significantly superior over 50% RDF + 12 t FYM ha^{-1} and FYM 24 tha^{-1} treatments. The grain weight per plant was recorded maximum with 75% RDF + FYM 6 tha^{-1}, which was at par with RDF alone and both these treatments were significantly superior over rest of the treatments.

Brar *et al.* (2001) reported that grain yield and stover yield of maize were significantly higher under 150 kg N + 41.3 kg P_2O_5 along with 10 t FYM ha^{-1} than rest of the treatment combinations. The application of FYM @ 2.5 t ha^{-1} resulted in grain yield better than that of gliricidia green leaf manure @ 5 t ha^{-1}.

Kumar and Puri (2001) observed that application of 90 kg N and 15 t FYM ha^{-1} gave maximum cob length, grains per cob, grain weight, stover and grain yield compared to 0 and 45 kg N ha^{-1} in maize.

Pattana shetti *et al.* (2002) reported that the application of FYM recorded significantly higher grain and stover yields of maize as compared to vermicompost and control and it was on par with poultry manure. The field trials conducted at Kanpur and Udaipur on maize showed that grain yield and stover yield (q ha^{-1}) were significantly higher under 10 to 20 t FYM ha^{-1} and also had significant and positive effect on green cob yield than control. (Mahala and Shaktawat, 2004; Verma *et al.*, 2006 and Khan *et al.*, 2008).

Wagh (2002) reported that all the growth characters of sweet corn *viz.*, LAI, AGR, leaf area and total dry matter production were found significantly more with application of 100 per cent RDF (225:50:50 kg N, P_2O_5 and K_2O ha^{-1}) + 5 t FYM ha^{-1} + *Azatobactor* + PSB than other fertilizer and FYM levels.

Chougale (2003) reported that the application of 100 % RDF + 5 t FYMha^{-1} + *Azotobacter* + PSB significantly improved all the growth and yield components of sweet corn.

Luikham *et al.* (2003) conducted a trial on baby corn to study the effect of organic and inorganic nitrogen at Coimbatore and the data showed that maximum plant height was recorded with 100% dose of N + 10 t FYM ha^{-1}, which was at par with 75 % dose of N + 10 t FYM ha^{-1} and both these treatments were significantly superior over control. The maximum dry matter production (g/m^2) was recorded with 100% N + FYM 10 t ha^{-1}, which was significantly superior over rest of the treatments, which included FYM.

Parasuraman and Mani (2003) observed that the diameter of cob, length of cob, grains per cob and grain weight per cob of sweet corn were significantly higher under 60 kg N ha^{-1} + 30 kg P_2O_5 along with 12 t FYM ha^{-1} than the remaining treatment combinations.

Rana and Shivran (2003) reported that number of cobs per plant, cob length, grains per cob, grains weight per cob and weight of maize cobs per plot were significantly higher under FYM @ 5 t ha^{-1} and dust mulch or straw mulch as compared to no mulch.

Jayaprakash *et al.* (2004) studied the growth parameters of maize with application of organic manures. The application of vermicompost @ 2 t ha^{-1} recorded significantly higher LAI compared to no organics and was on par with that of application of FYM @ 10 t ha^{-1}.

Kumar and Thakur (2004) reported that the yield attributes of maize *viz.*, number of cobs, grains cob^{-1} and 1000 grain weight decreased significantly where the fertility level was reduced to 50 per cent of recommended fertilizer (60+ 11.25+58.5 kg NPK) + 10 t FYM ha^{-1}

Tripathi *et al.* (2004) carried out a field trial at Raipur (Chhattisgarh) during summer season on maize and reported that diameter of cob, length of cob, grains per

Khadtare *et al.* (2006) carried out the research workat college farm of Anand Agricultural University, Anand during *Rabi* season of 2005-06 and reported that significantly higher values were recorded in respect ofcob girth, cob length and green cob weight in treatment T_{10} (RDF 150:50:0 NPKha^{-1}) followed by T_4 (75 % RDN + 25 % N through VC prepared from *Parthenium hysterophorous* L.) and T_6

(21.7%) (75% RDN+25% N through VC prepared from *Amaranthus spinosus* Linn.).

Waheeduzzama (2004) reported that the treatment combination of *Panchagavya* 4 per cent + 50 per cent RDF favourably influenced the plant height (32.40cm), number of leaves per plant (6.20), total leaf area (336.96 cm), suckers per plants (4.20) and flower yield per plant (5.90) in anthurium.

Karki *et al.* (2005) found the tallest plants with the application of recommended dose of fertilizer (120:26.2:41.5 kg NPK ha^{-1}) than remaining fertilizer levels at all the growth stages in maize except 60 days after planting. The dry matter accumulation $plant^{-1}$ of recommended dose of fertilizer being equal to the 120 kg N+10 t FYM+5 kg zinc ha^{-1} at 60 and 80 days after planting.

Kumar *et al*. (2005) conducted an experiment at Indian Agricultural Research Institute, New Delhi on maize and reported that application of 120 kg N + 26.2 kg P_2O_5 + 33.2 kg K_2O ha^{-1} combining with 10 t FYM ha^{-1} was significantly higher plant height and leaf area index over rest of treatment combination.

Patel (2005) conducted a trial on maize in sandy loam soil of Anand, Gujarat and reported that the plant height, dry matter accumulation per plant at 30, 60 DAS and at maturity, crop growth rate and days to mid taselling and silking were observed significantly the higher with 100 % RDF (100 N + 50 kg P_2O_5 kg ha^{-1}) along with seed inoculation with biofertilizers (ASA + PSB).

Thavanprakash *et al*. (2005) studied the effect of integrated nutrient management on growth and yield of baby corn and reported that growth attributes *viz.*, plant height, dry matter production, days to 50 per cent tasseling, initiation day to silking were significantly higher under 50 per cent NPK through either poultry or goat manures along with *Azospirillum* and phospho bacteria.

Gosavi (2006) reported that mean plant height at all stages, number of functional leaves at 60 DAS and harvest and dry matter production at all the growth stages, weight of cob with and without husk, length of cob, number of kernel rows cob^{-1}, number of kernels cob^{-1}, number of cobs per $plant^{-1}$ and kernels weight cob^{-1}, the green cobs yield, green stover yield and total biomass yield of sweet corn were influenced significantly due to application of recommended dose of fertilizer combination of FYM 15 t FYM ha^{-1} than control treatment.

Huq (2006) conducted a field trial at Shalimar Campus Kashmir and reported that, the combination of FYM and mineral fertilizer significantly increases the growth parameters of maize like plant height, leaf number and leaf area index.

Khadtare *et al.* (2006) carried out the research work at college farm of Anand Agricultural University, Anand during *Rabi* season of 2005-06 and reported that significantly higher values were recorded in respect of cob girth, cob length and green cob weight, green cob yield and green fodder yield of sweet corn (112.5 q ha^{-1} and 246.3 q ha^{-1}, respectively) in treatment T_{10} (RDF 150:50:0 NPK ha^{-1}) followed by T_4 (75 % RDN + 25 % N through VC.

Mahala *et al.* (2006) advocated that farmyard manure @ 10 t ha^{-1} had positive direct effect on grain and stover yields of maize. The yield and yield components of baby corn *viz.*, ear length, girth and weight of baby corn were higher with the application of recommended dose of fertilizers and 35 kg vermicompost over 100 per cent recommended dose of fertilizer and other treatments except recommended dose of fertilizer with combination of farmyard manure.

Prakash *et al.* (2006) studied on inter relationship and path analysis for yield improvement in sweet corn genotypes at Hyderabad and reported that sweet corn yield was significantly and positively associated with growth and yield attributes. Organic manures along with inorganic fertilizer and seed inoculated with *Azotobacter* and phospho solubilizing bacteria had pronounced effect on green cob yield and green fodder yield. These might be due to fixation of atmospheric N and secretion of growth promoting substances of *Azotobacter* and increased bacterial efficiency by phosphobacteria combined together might have increased the growth and yield.

Saha and Mondal (2006) reported that combined use of either biomax or neem seed powder or farmyard manure with 75 per cent of recommended dose of fertilizer resulted in taller plant with better other growth parameters of maize. Application of vermicompost @ 2 t ha^{-1} recorded significantly higher plant height, number of leaves, leaf area index, dry matter accumulation as compared to no organics and was on par with the application of farmyard manure @ 10 t ha^{-1}.

Zende (2006) reported that significantly the plant height, number of functional leaves and dry matter of sweet corn was increased with the increase in the fertilizer levels at all the crop growth stages, yield attributes *viz*., cob length, cob girth, number of grains, weight of grains cob^{-1} and number of cobs $plant^{-1}$ and weight cob^{-1}, cob yield and biological yield was recorded significantly superior with 150 per cent RDF with 3t

vermicompost over rest of the fertilizer levels.

Mahajan *et al.* (2007) conducted a field trial at Kangra district of Himachal Pradesh and reported that, the integrated used of both organic and inorganic manure has positive effect on the total productivity of maize crop than sole used of mineral fertilizer.

Thavaprakash and Velayudham (2007) reported that combined application of inorganic and bio fertilizers (*Azospirillum* and phospho bacteria) along with poultry manure produced higher cob yield (8037 kg ha^{-1}) than FYM incorporated with inorganic and biofertilizers (7243 kg ha^{-1}) and inorganic fertilizers alone (7335 kg ha^{-1}) in sweet corn.

Pawar and Patil (2007) reported the maximum grain yield of maize with the application of vermicompost@ 5 t ha^{-1} which was superior to all other treatment combinations.

Ashoka *et al*. (2008) reported that integration of RDF (150:75:40 kg NPK ha^{-1}) along with 25 kg $ZnSO_4$ 10 kg $FeSO_4$ and 35 kg vermicompost on baby corn-chickpea sequence resulted in significantly maximum yield and yield attributes namely, ear length, weight of ear, yield (64.43 q ha^{-1}) as well as green fodder yield (232.33 q ha^{-1}) over sole application of inorganic sources.

Gable *et al*. (2008) indicated that all growth parameters and yield of maize crop were significantly influenced by various integrated nutrient management treatments and were significantly highest with 100 per cent recommended dose of fertilizer followed by 75 % RDF + 25 % N through *leucaena* lopping + biofertilizer. Kumar *et al.* (2008) results indicated that among organic manures, application of vermicompost @ 2.5 t ha^{-1} with an increase in N level upto 120 kg ha^{-1} recorded significantly higher plant height, dry matter production in leaf, stem, cob, yield, yield attributes and returns of maize over controland it was found to be on par with application of FYM @ 10 t ha^{-1} with an increase in N level upto 120 kg $ha^{-1.}$

Sujatha *et al.* (2008) noted that the application of NPK @ 75:75:50 kg ha^{-1} + FYM @ 15 t ha^{-1} + *Panchagavya* @ 3 % foliar spray recorded the highest nutrient uptake, growth parameters, yield and and rographolide content followed by *Panchagavya* @ 3 % + FYM @ 15 t ha^{-1} + foliar spray recorded best yield.

Thavanprakash *et al.* (2008) studied the effect of integrated nutrient management on growth and yield of baby corn and reported that growth attributes *viz.*, plant height, dry matter production, days to 50 per cent tasseling, initiation day to silking were significantly higher under 50 per cent NPK through either poultry or goat manures along with *Azospirillum* and phospho bacteria.

Dadarwal *et al.* (2009) observed that the application of FYM 5 t ha^{-1} along with azotobacter + PSB recorded the highest seed yield of mustard (1642 kg ha^{-1}), followed by treatment receiving 25 % RDP + vermicompost 1.25 t ha^{-1} with *Azotobacter* + PSB (1600 kg ha^{-1}) and 25 % RDF + FYM 2.5 t ha^{-1} with *Azotobacter* + PSB (1594 kg ha^{-1}).

Nath *et al*. (2009) reported that the maximum number of cobs $plant^{-1}$ (1.2) was seen by giving the entire quantity of nutrients through fertilizers which was at par with 50 % fertilizer + 50 % vermicompost with and without seed inoculation. The maximum single cob weight, green crop, green fodder and biological yields in sweet corn were recorded when the entire quantity of nutrient was applied through chemical fertilizers which was significantly greater in comparison to the different other sources in question except fertilizers + vermicompost (50:50) + seed inoculation. Also the minimum yields were obtained by 100 % vermicompost application.

Radhakrishnan (2009) noted that the primarily attributed to better growth of plants in terms of accumulation of dry matter and height of plant per plant due to vermiwash spray which led to adequate supply of photosynthates as well as to direct supply of major and micronutrients to developing grains.

Chauhan (2010) reported that significantly higher stover yield in sweet corn were recorded with varying levels of nitrogen, but highest net return was obtained with 120 kg nitrogen with application of FYM@10 ha^{-1} per hectare. The strawer yield were increased significantly with increasing levels of nitrogen from 0 to 160 kg per hectare.

Gopal *et al*. (2010) reported that the treatment receiving three spays of vermiwash significantly produced higher seed (5306 kg ha^{-1}) and stover (7253 kg ha^{-1}) yield over on vermiwash spray. The improvement in grain and stover yield might be due to significant increase in yield components like length of ear, girth of ear and grains per ear which ultimately resulted into higher productivity.

Lazcano *et al.* (2011) showed that mixed application of 25 per cent rabbit manure vermicompost with 75 per cent mineral fertilizer produced no significant difference in sweet corn yield (37.21 g $plant^{-1}$) as compared to 100 per cent mineral fertilizer (39.18 g $plant^{-1}$).

Uwah *et al.* (2011) reported that the highest rate of

both fertilizers significantly increased plant height, leaf area index, number of grains cob^{-1} and also hastened tasselling sweet maize, whereas number of leaves plant^{-1}, number of cobs plant^{-1} and cob yield ha^{-1} obtained at the 10 or 15 t ha^{-1} PM and 80 or 120 kg N ha^{-1} were statistically similar. Total dry mater (TDM), weight of grains cob^{-1} and total grain yield, peaked at 10t ha^{-1} PM and 80 kg N ha^{-1} fertilizer. At 10t ha^{-1} PM and 80 kg N ha^{-1} rates, TDM yield increased by 41 and 37 per cent and grain yield by 42 and 39 per cent, respectively compared with the control treatments. The combination of PM at 10 t ha^{-1} with N at 80 kg ha^{-1} maximized TDM, cob yield ha^{-1} and total grain yield.

Ali *et al.* (2012) a field trial was conducted at University of Agriculture Faisalabad Pakistan in their Agronomic trial field and the result shows that, the combining ability of poultry manure with single super phosphate result in positive increase in growth parameter of maize such as leaf area index and crop growth rate.

Ravi *et al*. (2012) in their research trial conducted at agricultural research station Arabhavi of Karnataka and they also confirmed that, the use of 75 per cent RDF with other organic and bio-fertilizer significantly increases the grain yield of quality protein maize.

Sarwar *et al*. (2012) the study revealed that maximum maize grain yield, *viz.*, 5.18 t ha^{-1} was obtained with 75+25 % (CF + FYM) and 4 kg Zn ha^{-1}. It was statistically at par with treatment having 50 + 50 % (CF + FYM) and 4 kg Zn ha^{-1} as well as 75 + 25 % and 8 kg Zn ha^{-1}. Zinc application also enhanced maize grain yield by 12 per cent over treatment where no Zn was applied *i.e.* 4.08 t ha^{-1}.

Bunker *et al.* (2013) concluded that among the different treatments of nutrient management, treatment 100 % NPK + farmyard manure @ 5 t ha^{-1} recorded significantly higher plant height at harvest (228.65 cm), dry matter accumulation at harvest (183.10 g plant^{-1}), weight cob^{-1} (135.56 g), cob length (18.47 cm), weight of grains cob^{-1} (99.90 g), shelling percentage (78.60), 1000- grains weight (211.81 g), grain yield (4292 kg ha^{-1}) and stover yield (5647 kg ha^{-1}) in maize.

Kannan *et al.* (2013) the results revealed that leaf area, plant height and yield parameters like number of grains per cob, 100 seed weight and yield (4112 kg ha^{-1}), weight of the cob inmaize was recorded maximum in INM practice including FYM and recommended dose of NPK as compared to other treatments.

Kanu Murmu *et al.* (2013) reported that in sweet corn with significantly dry matter and yield was higher as compared to the treatments with sub-optimal dose of nutrients (vermicompost 50 + crop residue and vermicompost 50 + vermiwash + bio fertilizer) in both the years.

Keerthi *et al.* (2013) reported that among the fertility levels tried, application of 180-75-60 kg N P K ha^{-1} + vermiwash at 20, 35 and 50 DAS recorded the highest growth parameters, yield attributes and cob yield which was however, found parity with 180-75-60 kg NPK ha^{-1} + vermicompost of sweet corn.

Lone *et al.* (2013) reported that application of farm yard manure (FYM) at 6 t ha^{-1} in combination with 150 per cent recommended dose of fertilizer (225N:90 P_2O_5: 60 K_2O kg ha^{-1}) reveled maximum cob yield (without husk) of baby corn 20.60 q ha^{-1} associated with maximum number of cobs plot^{-1} (326).

More *et al.* (2013) concluded that all the yield contributing characters, highest grain yield (5261 kg ha^{-1}) and stover yield (7405 kg ha^{-1}) in sweet corn were obtained from the 50 per cent nitrogen through chemical fertilizer + 25 % through biocompost + 25 % through vermi-compost. The use of vermiwash imparted a rise of 11.21 per cent grain and 10.28 per cent stover yield over control.

Kolari *et al.* (2014) revealed that highest dry matter, 100 kernels weight and yield production of maize belonged to enhanced by two nitrogen levels, N: (0 and 150 kg ha^{-1}) and two vermicompost levels, V: (0 and 15 ton ha^{-1}).

Mahmooda *et al.*(2014) showed that the integrated application of 150 or 200 kg N ha^{-1} and 10 or 12 t FYM ha^{-1} were found best combination for obtaining maximum stem girth and significantly increased green fodder yield of maize.

Rasool *et al.* (2015) results revealed that application of T_{10}- 75 % (NPK) + FYM (4.5 t ha^{-1}) + Biofertilizer (*Azotobacter* + Phosphate solubilizing bacteria (PSB) significantly increased the number of days taken to tasseling, silking and milky stages and various other growth characters *viz.*, plant height, leaf area index, dry matter accumulation cob yield with and without husk, fodder yield and green biomass yield of sweet corn whereas, the lowest values of these parameters were recorded in unfertilized control.

Sanjivkumar (2015) the results revealed that highest grain yield of maize 4402 kg ha^{-1} was recorded in treatment that received vermicompost @ 5t ha^{-1} with 75 per cent recommended dose of fertilizer (RDF) and it was found to be superior to over treatments.

Sayfallah *et al.* (2015) indicated that the plant height increased from 169.1 cm (control plants) to 206.7 cm in 10 t ha^{-1} by the application vermicompost and phosphorus.

Simon and Balabbo (2015) study revealed that the use of the different inorganic fertilizer and vermicompost combinations showed positive and significant effect on the growth and yield performance of sweet corn as gained the highest yield with a mean weight of 22,494 kg ha^{-1}, followed by 75 % Inorganic fertilizer + 25 % vermicompost and the least was control (no fertilizer) 15,500 kg ha^{-1}.

Syahmi *et al.* (2015) revealed that were mixture of 25 per cent vermicompost (VC) and mineral fertilizer (MF) increased the fresh yield and total above ground dry matter biomass of sweet corn than the conventional rate of mineral fertilizer application.

Khidrapure *et al*. (2016) concluded that the application of 50 % RDN through VC+50% RDF through inorganic fertilizers + $ZnSO_4$ @ 10 kg ha^{-1}+ *Azospirillum* @ 500 g ha^{-1}+ PSB @ 500 g ha^{-1}+ FYM @ 10 t ha^{-1} was found better in order to obtain more seed yield in hybrid seed production of maize (Arjun).

Gunjal (2017) reported that the application 125 % RDN + 25 % N through VC to sweet corn found suitable for maximum growth and yield attributes, green cob yield, biological yield, harvest index, quality parameters and maximum total uptake of sweet corn during *Kharif*.

Quality characters:

Koteva (1995) observed the increased protein content in grain with increase in fertilizer rates. Grain quality was considered best at 100 kg N, 60 kg P_2O_5 and 60 kg K_2O ha^{-1}. The TSS (%) and protein content (24.13 %) in seeds increased with increasing levels of phosphorus upto 60 kg ha^{-1} to pea crop.

Kamalakumari and Singaram (1996) reported after a field trial conducted at Coimbatore on maize that reducing sugar, total sugars, crude protein, starch, total carbohydrates and phenol percentage improved under application of 100 kg N : 40 kg P_2O_5 : 40 kg K_2O along with 10 t FYM ha^{-1} than rest of the treatment combinations. The increase in protein content (13.57 %) and carbohydrate content (65.34 %) under 150 kg N + 41.3 kg P_2O_5 along with 10 t FYM ha^{-1} than rest of the treatment combinations.

Singaram and Kamalakumari (1999) reported that the application of 100 per cent RDF + 10 t FYM ha^{-1} improved the quality of maize grain by enhancing the sugar, starch and crude protein content.

Brar *et al*. (2001) results indicated that the total uptake of N by hybrid maize increased with increase in nitrogen level and FYM, due to better proliferation of root system resulting in better absorption of water and nutrients significantly increases the protein content (12.45 %) and carbohydrates content (67.23 %), respectively.

Parmar and Sharma (2001) results indicated after a field trial conducted on maize that reducing sugar, total sugars, crude protein, starch, total carbohydrates and phenol per centage improved under application of 100 kg N : 40 kg P_2O_5 : 40 kg K_2O along with 10 t FYM ha^{-1} than rest of the treatment combinations.

Duraisami *et al*. (2002) reported that application of nitrogen at 120 and 240 kg ha^{-1} along with FYM and coir pith significantly increased the protein content (13.45 %) and carbohydrates content (73.00%) in maize, respectively.

Wagh (2002) reported after a field trial conducted at College of Agriculture, Pune on sweet corn that protein content in grain and green fodder, sucrose content in grain and brix reading of grain were not affected significantly but slightly improved under application of 100 per cent RDF (225:50:50 kg NPK ha^{-1}) + 5 t FYM ha^{-1} + *Azatobactor* + PSB than other fertilizer and FYM levels.

Arunkumar *et al.* (2007) reported that recommended dose of fertilizer to grain maize (112.5 + 75.0 + 37.5 kg NPK ha^{-1}) was found to be necessary to increase the quality parameters *viz.*, non-reducing sugars, total sugars and protein content of sweet corn. Reduction of N below 75 per cent and P and K below 100 per cent of recommended dose of grain maize not only accounted for reduction in total sugar and protein content but also sweetness of grains.

Almodares *et al*. (2009) reported that application of 200 kg ha^{-1} urea had the highest biomass (64.80 t ha^{-1}) and protein content (8 %) and it had the lowest soluble carbohydrates (12.80%) and fibre contents (31.90 %). Between fodders, corn had higher biomass and protein content (72.80 t ha^{-1}, 7.10 %) than sweet sorghum (66.50 t ha^{-1}, 5.90 per cent, respectively.

Dalvi *et al*. (2009) reported that reducing sugar, non-reducing sugar and total sugars increased by supply of nitrogen either inorganic fertilizers alone or in combination with FYM or vermin compost in the proportion of 50 per cent each enhanced the sugar content. The enhanced sugar content of sweet corn by inorganic fertilizers or in combination with FYM and vermin compost might be because of more availability

of nitrogen.

Singh and Nepalia (2009) evaluated that application of 125 % RDF significantly enhanced protein content (13.5 %) in maize compared to 100 % (10.34 %) and RDF 75 % (9.87%). The integration of FYM or vermicompost with chemical fertilizers was found equally effective with respective to protein content in maize.

Oktem *et al*. (2010) reported that protein content of sweet corn increased with increasing N supply.

Waghmode *et al.* (2010) reported that the integrated application of RDF with cow urine @ 10 % spray recorded significantly higher protein content which was on par with RDF with panchagavya @ 3 % spray (10.18 %). Significantly higher reducing sugar content (3.65 %) was noticed in treatment receiving RDF. Among liquid organic manurial treatments significantly higher reducing sugar (3.50 %) was observed in *Panchagavya* @ 3% spray over rest of the treatments. The integrated application of RPP and RDF along with all liquid organic manures helped in improving the quality parameters of sweet corn.

Singh *et al.* (2012) showed that application of FYM @ 10 t ha^{-1} enriched with 150 % RDF recorded significantly increased protein content in grain (11.84 %) over rest of the treatments in maize.

Lone *et al*. (2013) reported that application of farm yard manure (FYM) at 6 t ha^{-1} in combination with 150 % recommended dose of fertilizer (225 N : 90 P_2O_5 : 60 K_2O kg ha^{-1}) reveled maximum total soluble sugars (T.S.S) content (11.20 ^{0}Brix) in controlled pollinated cobs of baby corn.

Wailare (2014) observed that one hundred grams of baby corn are found to be rich in 89.1 per cent moisture, 1.9 g protein, 0.2 g fat, 0.06 g Ash, 8.2 mg carbohydrate, 28 mg calcium, 86 mg phosphorus and 11 mg ascorbic acid in application of integrated nutrient management on baby corn (*Zea mays* L.).

Sanjivkumar (2015) the results revealed that application of vermicompost @ 5t ha^{-1} + 75 per cent RDF increased the crude protein (16.67 %) and starch (81.34 %) content in maize crop and it was followed by the treatment which received sewage sludge 2 t ha^{-1} with 75 % RDF and green leaf manure @ 12.5 t ha^{-1} whereas the lowest value was recorded in control plot, respectively.

Syahmi *et al.* (2015) revealed that the increase in protein content (13.57 %) and carbohydrate content (65.34 %) under 150 kg N + 41.3 kg P_2O_5 along with 10 t FYM ha^{-1} than rest of the treatment combinations in maize.

Uptake of nutrients:

Yadav *et al*. (2006) also observed that use of FYM proved the best in term of maize nutrient uptake.

Kumar *et al.* (2007) results indicated that among inorganics, application of 100 per cent RDF with vermicompost @ 2.5 t ha^{-1} recorded significantly higher dry matter production in leaf, stem, cob, yield and yield attributes and uptake of nitrogen, phosphorus and potassium which consequently resulted in higher yields and returns in sweet corn.

Thavaprkaash and Velayudham (2007) reported that the highest uptake of N (192.7 kg ha^{-1}), P (25.0 kg ha^{-1}) and K (379.5 kg ha^{-1}) was noted due to combined application of inorganic, biofertilizers and poultry manure in sweet corn.

Rao *et al*. (2010) also suggested that, the integrated application of nutrients in maize grown under rain fed maintain and sustain soil resources. The nutrients (NPK) uptake was found to be significantly higher due to integration of 50 % RDF along with either poultry manure or FYM than sole application of 100 % RDF.

Waghmode *et al.* (2010) results indicated that the maximum uptake of N, P_2O_5 and K_2O in sweet corn was observed due to combined application of FYM (7.5 t ha^{-1}) with RDF and zinc sulpahte @ 10 kg ha^{-1} (253.1, 24.42 and 177.1 kg ha^{-1}, respectively).

Sannathimmappa *et al.* (2011) reported that higher nitrogen uptake (139 kg ha^{-1}), phosphorus uptake (58 kg ha^{-1}) and potassium uptake (131 kg ha^{-1}) and highest grain and stover yield of maize (4,689 kg ha^{-1} and 6.68 t ha^{-1}, respectively) was observed in treatment 8 *i.e.* 75 kg N through inorganic fertilizer, 25 kg N through compost, *Azospirillum*, recommended P and K with french bean intercrop.

Sarwar *et al.* (2012)the study revealed that highest N uptake in maize 98.7 kg ha^{-1} was observed with 50 % + 50 % (CF + FYM) and 8 kg Zn ha^{-1} application. The study revealed that substitution of 25 or 50 % N with FYM + 4 kg Zn ha^{-1} performed better than 100 % N fertilizer alone, with respect to leaf area index, grain and straw yield, soil organic matter content and nutrient uptake.

Bunker *et al.* (2013) concluded that among the different treatments of nutrient management, treatment 100 % NPK + farmyard manure @ 5 t ha^{-1} recorded significantly higher nitrogen (329.28 kg ha^{-1}), phosphorus (27.10 kg ha^{-1}) and potassium (309.12 kg ha^{-1}) contents

in soil after harvest of maize crop.

Keerthi *et al.* (2013) results showed that sweet corn crop supplied with the highest level of NPK integrated with vermiwash or vermicompost registered the highest values for N P K uptake by cob as well as stover to rest of the treatments tried. The lowest NPK uptake by cob and stover was registered with absolute control.

Mahmooda *et al.* (2014) showed that integrated application of 150 or 200 kg N ha^{-1} and 10 or 12 t FYM ha^{-1} were found best combination for obtaining nitrogen concentration, nitrogen uptake by plants and green fodder yield of maize.

Rameh *et al.* (2014) revealed that application of recommended dose of inorganic fertilizer along with lime, FYM and biofertilizers to maize, if adopted properly, can lead to many-fold improvement in soil fertility in terms of higher uptake N, P, K, available organic carbon and exchangeable bases on acidic soils of Meghalaya and other north-eastern states of India with similar soils.

Sanjivkumar (2015) the results revealed that application of vermicompost @ 5t ha^{-1}+75 per cent RDF recorded the highest calcium and magnesium content in pot harvest soil sample (0.139 and 0.281 %). The vermicompost along with inorganic fertilizers were higher uptake N, P, K, by maize crop for their growth and development and also maintained soil fertility and increased yield.

Economics:

Singh and Sarkar (2001) reported after a field trial conducted at Birsa Agricultural University, Ranchi on maize that net returns (Rs. 24606, 25242 ha^{-1}) and B:C (3.4, 3.5) ratio in both the years was significantly higher in 75 % N, P_2O_5, K_2O + poultry manure and (Rs. 22509, 23748 ha^{-1}) and B:C (2.9, 3.0) ratio in 75 % N, P_20_5, K_2O + FYM (Rs. 19454, 23302 ha^{-1}) and B:C (2.6, 3.1) ratio and lowest in 75 % N, P_2O_5, K_2O + poultry compost (Rs.18206, 20529 ha^{-1}) and B:C (2.7, 3.0), 100 % N, P_2O_5, K_2O (Rs. 18775, 22963 ha^{-1}) and B:C (2.3, 2.7) ratio. The gross income and net profit were higher with application of FYM @ 5 t ha^{-1}, which was significantly superior over control.

Kumar *et al.* (2005) revealed that the highest net returns ha^{-1} (Rs. 11,443) and net returns per rupee invested (Rs. 1.12) were obtained with 100 per cent NPK (120+26.2 + 33.2 kg NPK + 5 t FYM ha^{-1}) in maize.

Sahoo and Mahapatra (2005) reported after a field trial conducted at Jashipur on sweet corn that the maximum net profit of Rs.11,500 ha^{-1} and B:C ratio of 2.05 under of 120 kg N, 26.2 kg P_2O_5 and 50 kg K_2O ha^{-1} over control and fertilizer levels. The application of 50 % RDF + vermicompost 2.5 t ha^{-1} + FYM 5 t ha^{-1} and 50 % RDF + vermicompost 5 t ha^{-1} + 10 t FYM ha^{-1}, these two treatments yielded net returns of Rs. 60025 and Rs. 57283 ha^{-1}, respectively, which owing to higher cost of vermicompost and FYM, were 5.5 and 10.9 per cent lower than 100 per cent RDF.

Bhagat *et al.* (2006) reported the highest net monetary returns and benefit : cost ratio when the sole sweet corn is supplied with 125 per cent RDF+ 5 t FYM ha^{-1}.

Jat (2006) reported that the highest gross monetary returns, net monetary returns and benefit cost ratio with 100 per cent RDF + 5 t FYM ha^{-1}in sweet corn.

Kar *et al.* (2006) reported that application of nitrogen from 0 to 80 kg ha^{-1} + 5 t FYM ha^{-1} gave significantly higher net returns (Rs. 32,086 to Rs. 61,532 ha^{-1}) and benefit: cost ratio (1.73 to 3.76) of sweet corn during *Kharif* season in sandy loam soils of Bhubaneshwar.

Zende (2006) reported that the cost of cultivation, gross returns, net returns and B:C ratio of sweet corn were recorded maximum with the 150 % RDF+ 5t FYM ha^{-1} level followed by 100 % RDF, 50 % RDF and lowest with control during both years.

Bindhani *et al.* (2007) concluded that in baby corn net returns and benefit : cost ratio were highest with 120 kg N ha^{-1}, which resulted in significant increase of 289.2, 69.8 and 39.15 per cent in net returns and 235.2, 57.7 and 34.1 per cent in benefit : cost ratio compared to that of the no nitrogen, 40 and 80 kg N+ 5t FYM ha^{-1}, respectively.

Kumar *et al.* (2007) results indicated that among inorganics, application of 100 per cent RDF recorded significantly higher net returns (Rs. 20,898 ha^{-1}) and B:C ratio (2.41) over 50 per cent RDF + 5t FYM and it was found to be on par with 75 per cent RDF of sweet corn.

Kumar *et al.* (2008) revealed that RDF (150:75:40 kg N, P_2O_5 and K_2O ha^{-1}) + 25 kg $ZnSO_4$ + 10 kg $FeSO_4$ + 35 kg vermicompost $ha^{-1}$of sweet corn gave highest gross returns (Rs. 96838 ha^{-1}), net returns (Rs. 76889 ha^{-1}) and B:C ratio (3.85).

Suryavanshi *et al.* (2008) reported significantly higher gross returns, net monetary returns and benefit: cost ratio with 150 kg nitrogen ha^{-1} as compared to either 50 and 100 kg nitrogen + 5t FYM ha^{-1}. There was marked improvement in net returns with each successive increase in nitrogen level from 0 to 120 kg ha^{-1} in maize.

Kumar (2009) reported that the maximum net returns of Rs. 49.57 thousands ha^{-1} was noticed with 120 kg N ha^{-1}, which was 560.9, 64.5 and 10.0 per cent higher over 0, 40 and 80 kg N ha^{-1} in sweetcorn. The net returns $rupee^{-1}$ invested was also enhanced with higher nitrogen levels, but significant improvement was found upto 80 kg N ha^{-1}+ 5t FYM.

Dadarwal *et al.* (2009) reported that significantly higher net returns (Rs. 26815 ha^{-1}) and B:C (2.83) invermicompost top dressing + GLM over basal application of vermicompost + green leaf manure treatment in baby corn.

Nath *et al.* (2009) reported that the maximum net returns (Rs. 37, 000 ha^{-1}) were achieved by applying (110 kg N +55 kg P_2O_5 ha^{-1}), but this was at par to 90 kg N +45 kg P_2O_5 ha^{-1} and 70 kg N +35 kg P_2O_5 ha^{-1} of sweetcorn. The minimum NR were obtained by applying lowest of nutrient (50 + 25 kg N and P_2O_5 ha^{-1}). However, the fertility levels did not show perceptible change in B:C. The maximum net returns and B:C were observed with 100 % chemical fertilizers+ 5t FYM.

Zende *et al.* (2009) an experiment was conducted at the Department of Agronomy, Dr. B.S.K.K.V. Dapoli (M.S.) during the *Rabi* season of 2004–2005 to study the effect of nutrient management on sweet corn (var. Sugar 75). The growth, yield attributes, yield, quality and economics of the sweet com were significantly superior with 150 % RDF level over control, 50 % RDF and 100 % RDF levels. The highest B: C ratio of 2.59 was recorded with 150 % RDF level.

Chauhan (2010) reported that application of organic matter FYM @ 10 with 120 and 160 kg N ha^{-1}, respectively was significantly increased the net realization of Rs. 30525 and 29255 ha^{-1} and seed inoculation gave Rs. 31485 ha^{-1} in sweet corn.

Kumpawat (2010) observed that maximum net returns (Rs. 50342 ha^{-1}) with B:C ratio (3.2) in pearl millet was obtained from treatment receiving 25 % RDF + FYM 2.5 t ha^{-1} with *Azotobacter* and PSB in pearl millet.

Waghmode *et al.* (2010) study revealed that the significantly higher net returns (Rs.35,250 ha^{-1}) of sweet corn were realized with the combined application of RPP with bio-digester liquid manure.

Ghaffari *et al.* (2011) revealed that the best nutrient management practice of maize where one spray of multi-nutrients was applied in conjugation with recommended dose of NPK@ 200:20:25 kg ha^{-1} attaining Rs. 41,170 net field benefits.

Shah *et al.* (2011) reported that among the fertilizer levels, application of 100 per cent RDF+ FYM 2.5 t ha^{-1} showed significantly the highest net return and benefit cost ratio in *Rabi* sweet corn.

Tetarwal *et al.* (2011) revealed that application of 150 % RDF (N 60 P 22.5) produced significantly higher net return (19251 ha^{-1}) and B:C ratio (1.90) compared to control in rainfed maize.

Bunker *et al.* (2013) concluded that among the different treatments of nutrient management the highest net return (Rs. 39526 ha^{-1}) and BCR (2.56) were recorded with the application of 100 % NPK + farmyard manure @ 5 t ha^{-1} followed by application of 125 % NPK (Rs. 36462 ha^{-1}) along with BCR value of 2.49. The lowest net return (Rs. 6578 ha^{-1}) and benefit cost ratio (1.34) were recorded under the control in maize.

Lone *et al.* (2013) reported that cultivation of baby corn variety VL-78 under temperate conditions with an application of N:P:K at 90N:60P:40K kg ha^{-1} in combination with 6 t ha^{-1} FYM revealed a maximum B:C ratio of 1:1.59. With 703 $ ha^{-1} as cost of cultivation, the estimated gross returns from the cultivation practice were to the tune of 1825 $ giving a benefit of 1123 $ ha^{-1} in baby corn.

Mathukia *et al.* (2014) results revealed that application of 120-60 kg N-P_2O_5 ha^{-1} improved growth and yield attributes and ultimately higher green cob and fodder yields with higher net returns and B:C ratio over control and 90-45 kg N-P_2O_5 ha^{-1} from *Rabi* sweet corn.

Simon and Balabbo (2015) study revealed that yields of sweet corn from pure inorganic obtained the highest net income and ROI with 1242.38 per cent followed by control (no fertilizer) with 1140.71 per cent and 75 per cent inorganic fertilizer + 25 % vermicompost with 964.78 per cent.

Gunjal (2017) reported that the application 125 % RDN + 25 % N through FYM obtained the highest net income and B:C ratio to minimize the cost of production along with sustained corn yields.

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