Review Article

Nitrogen management in baby corn: A review

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ABSTRACT

Baby corn (*Zea mays* L.) is a short duration crop, relatively new introduction in India and a potential option for raising farmer's income being a high value crop. This crop may open new alternatives since fits well in the cropping systems and grown year round in a wide range of climatic conditions. Production technologies of baby corn differ from maize thus, development and standardization of location specific agro-techniques are required before popularization among the farmers. Nitrogen (N) deficiency is a wide spread phenomenon in Indian soils and its proper management is of enormous significance from economic and environmental point of view. Efficient utilization depends on the right time, method and optimum N application synchronizing with the crop demands. Studies so far suggest N application in variable rates and proportions for different agro-ecological zones. Yield increases with N rates up to certain level but optimum economic N dose is found independent of plant densities. Baby corn-legume intercropping may be a viable option to improve N-fixation and system productivity. More studies needed on N management in baby corn based cropping systems. Integrated nutrient management (INM) practice should be adopted as core strategy for sustainability and reduce dependency on chemical fertilizers. Combined approach (soil application + foliar spray) enhances yield and quality in winter baby corn. Concentration and timing of urea foliar spray are two crucial factors to harness the desired benefit. Scope to harvest combined product (baby corn + green / mature cob) and its interaction with N may be explored to provide more flexibility to the farmers. Optimization of N quantities depends on season and location. Site specific nitrogen management (SSNM) approach can address the spatial and temporal variations for efficient N-management. However, cost effective and user's friendly precision tools may be a viable option considering the real farm situations.

Keywords: Baby corn, Genotypes, Foliar fertilization, Nitrogen management

1. INTRODUCTION

Maize (*Zea mays* L.) is widely cultivated in subtropical, tropical and temperate regions and ranked third most important cereal crop in the world. Baby corn is dehusked baby cob harvested prior to fertilization after emergence of 2-3 cm long silk [1]; nutritious vegetable rich in sugars, proteins, vitamin C and by products *viz.* tassel, silk, husk and green stalk are valuable cattle feed. This crop is a promising alternative because of fast growth, short duration, high yield and profit, fits well in the cropping systems and may open avenues for value addition, crop diversification and revenue generation. Crop duration varies with season *i.e.* 60-70 days (rainy), 120-140 days (winter) and 75-90 days (spring). Nitrogen performs numerous functions and is an essential component of amino acids the building blocks of proteins, constituent of nucleic acids, DNA and RNA, chlorophyll molecule, cell walls and plant compounds including amines, amides and nucleotides. Nitrogen plays important role in plant growth and development, photosynthesis, physiological and biochemical reactions in plant metabolism. Soil available N often found low due to prevalence of high temperature and low organic matter. Maize prefers both ammonium (NH_4^+) and nitrate (NO_3^-) form and nourishing both increases plant growth and yields than NO_3^- alone. The deficiency of N may cause chlorotic condition, yellowing, stunted growth and yield reduction. Nitrogenous fertilizers are conventionally applied in more quantities by the Indian farmers. Generally they apply N based on greenness of the leaf colour, a visual indicator to judge crop N status. Excess application often result N losses, leads to reduction in nitrogen use efficiency (NUE). Plant receives N primarily as inorganic NH_4^+ and NO_3^- ions by roots from rhizosphere. Indigenous soil resources and N applied as fertilizer input both facilitate to form available N pool to plants in a single cropping cycle represent only a small fraction (1-4%) of total soil N. Indigenous supply includes N derived by the crop from inorganic N pool, mineralization of soil organic matter and crop residues, biological N_2-fixation, atmospheric deposition and irrigation water. Biological N_2-fixation by legumes and other microorganisms are the second largest source of N input after inorganic N. Low NUE is an issue of great concern in cereal production systems. Spatial and temporal variations are obvious in supply of nutrients from soil and in crop requirement. Several factors *viz.* soil properties, genotype, yield goal are important in deciding nutrient requirement besides other management practices and climatic variations. Added N not utilized by the crop or immobilized organic N from soil pool are vulnerable to loss by leaching, volatilization and denitrification. Hence, NUE of a crop/cropping system may be improved by enhancing the uptake efficiency of applied N and minimizing losses from soil pool [2]. Uniform applications ignore spatial variations in crop demand for N, mismatch between fertilizer N supply and demand, and limitations in accounting of temporal variations and its influence on crop need are the prime reasons responsible for low NUE. Inaccurate applications of fertilizer N in terms of quantity and timing causes poor synchronization. In fact proper synchrony between N supply and demand considering spatial and temporal variations in soil decides the extent of achievable yield, profit and protection to environment [3].

Nitrogenous fertilizers are costly therefore their indiscriminate use calls agronomists to re-think its management for efficient utilization. Variable crop responses to N rates and time of application noticed over different agro-ecological zones suggest need of area specific recommendations. Ideal management focuses on minimizing leaching losses, optimize yield and profit to enhance NUE. Mid season N application at critical growth stages are beneficial to maintain continuous supply, enhance NUE and in restricting possible losses. Baby corn productivity depends on the dry matter accumulated and its efficient partitioning to economic plant part (baby cob). Remobilization of accumulated source during the initial growth phase and its effective conversion to sink is critical for enhancing baby corn yield. The final yield depends on the storage of the pre-anthesis assimilates which also modified due to the factors like genotypes and N fertilization. Deficiency of N is the prime factor limiting economic yield of baby corn. Over application of N is also a common problem in the cereals. Efficient use minimizes nitrate leaching to ground water and enhances NUE. Key interventions for successful management of a soil nutrient are correct diagnosis of deficient nutrient, quantification of accurate fertilizer doses, enhancing nutrient use efficiencies, use of bio fertilizers and organic sources. Baby corn is relatively a new crop thus limited research work available under Indian conditions [4]. Agronomic management of baby corn differs from grain maize because of its lesser crop duration, early harvesting and grower’s interest in production of more baby cobs. To exploit higher productivity specific genotypes, spacing, plant population density, detasseling and fertilizer application particularly adequate N supply are important. Optimization of crop yields depend upon important yield building factors *viz.* genotypes, site specific optimum plant population and plant nutrition.

2. PLANT DENSITY × NITROGEN

Optimum plant population with adequate fertilization are key factors to exploit the full potential of the genotype. Baby corn may be planted at 40 × 20 cm spacing with N 150-200 kg/ha to harvest maximum yield. Further increase in plant population enhances operating expenses with reduction in yield and net returns [5]. Growing baby corn at wider spacing (45 × 30 cm) significantly enhanced yield attributes and sensory parameters while nutritional parameters were unaffected. Wider spacing with optimum fertilization improves baby corn yield and digestibility of green fodder. Values of nutritional parameters (protein, phosphorous, potassium, calcium and crude fibre content) significantly enhanced except sugars and ascorbic acid from lower levels up to optimum fertilization [6]. Baby cob yield positively influenced and even at same plant population adoption of wider row spacing (75 × 16 cm) proved beneficial than narrow (60 × 20 cm). Keeping wider distance between rows provides better spatial arrangement to individual plants which lead to effective utilization of nutrients, moisture and light. Hence, improve plant height, leaf area index (LAI), total dry matter partitioning with baby cob and fodder yield [7].

Genotypes do not respond to density after a certain limit and response to density is location dependent. Therefore, farmers should adopt higher plant density recommended for each ecological zone determined on the basis of experimentation. Total interception of photosynthetically active radiation increases with increase in the plant density and helps in compensating substantially high yield. Nitrogen availability to crop varies with the weather conditions particularly due to rainfall pattern. Increase in N levels and application in 4-5 splits results enhance yield and quality irrespective of high or low planting densities. Location specific N-management required to sustain production in various agro-ecological zones [8]. Economic optimum N dose is independent of plant population. In drylands, increase in plant population up to certain extent increases yield and thereafter inconsistent response noticed due to variable moisture. Hence expected yield, crop and fertilizer prices relationship are also important considerations.

3. GENOTYPE × NITROGEN

Variations in the crop demands with genotypes are obvious because of their varied production potential and genetic makeup. Baby corn requires an early maturing, medium stature, prolific cultivar with uniform flowering. Genotype with desirable traits is the most critical issue for successful cultivation of baby corn. Single cross hybrids have better production potential than composites since more uniform in flowering, ready for harvest in short time. Absence of suitable genotype may cause severe reduction in yield (30-35%). Higher yield require accommodation of greater plant density thus short stature genotype is suitable to avoid competition and lodging. The current practice is to use any of the available maize variety (composite/hybrid) for baby corn cultivation which often lack important productive traits. Genotypes differ in their genetic ability and usually exhibit varied physiological response to utilize applied nitrogen. However, full exploitation of the genetic potential largely depends on the management practices which plays crucial role. The factors important for efficient N-utilization are responsive genotypes, application time, method and sources of N [9].

Quality traits of 20 maize genotypes grown as baby corn during rainy and winter seasons showed wide range of variability in morphological and nutritional characteristics. Single cross hybrid HM 4 possessed most desirable morphological and nutritional quality traits while HQPM 1 was next best. Six yield traits *viz.* husked cob yield/plant, dehusked cob yield/plant, number of cobs/plant, fodder yield/plant, days taken to picking of first and last cob are considered important in elite cultivars for their direct role in baby corn production. Strategic emphasis given to single cross hybrids proved instrumental in raising maize productivity in the recent past. Similar approach may be utilized for baby corn [10]. Maize genotypes differ in efficiency to assimilate total dry matter and the interaction between genotypes and N levels had significant effect on remobilization of total dry matter from plant and stem. An apparent estimation of contribution between anthesis to grain filling indicated varied efficiencies of genotypes in total dry matter remobilization (17.81-22.73%) and total dry matter remobilization from stem (10.09-17.57%) which reduced with increase in the N levels. Enhance N level is related to quantum of photosynthetic surface and is associated to the total sink activity. Yield components and yield significantly increased up to the highest level of N (180 kg/ha) irrespective of genotypes. The best performing genotype produced significantly greater yield over others [11].

Genotypes play vital role in determining the yield if other input factors and conditions are kept identical. Yield potential of winter baby corn genotypes differed and cobs/plant and their length were found chief parameters. Genotypes took more time to first silking (85 days), were more productive and significantly enhanced yield up to 160 kg N/ha while those with early silking (71 days) responded only up to 120 kg N/ha. Growth parameters, yield attributes and yield significantly improved up to 160 kg N/ha for two genotypes while it was 120 kg/ha for another two genotypes tested. Genotypes vary in their potential to utilize N and respond differently to variable rates of N application. Actually, N is the constituent of protein and nucleic acid hence optimum fertilization promotes plant growth by synthesizing greater protein and chlorophyll and improves plant height, dry matter accumulation, LAI and crop growth rate. Increase in dry matter with N levels indicates that limited N adversely affects dry matter production. Differences observed were larger at later crop stages than early stages [12]. Efficient genotypes respond positively to N application and produce high yield. Nitrogen use efficiency reduces with increase in the levels of N irrespective of genotypes and reductions in efficiencies at high levels are obvious. Selection of an efficient genotype with relatively acceptable NUE reduces wastage of N which otherwise threat to pollute the environment [13].

Assessment of nutrient ratios at maturity (whole plant) indicated that variations in N/P ratio was due to genotypes only while N/K ratio varied because of both genotypes and N application schedules. The values of N/P and N/K ratio noted were 6.34 & 6.88 for hybrid HM-4 and 1.28 & 1.22 for composite Azad Uttam. Nutrient ratios expressed are proportionally associated with N level applied, content of respective nutrient and the dry matter produced. Reduction in number of split applications (N) from four to two also reduced N/K ratio. Nutrient harvest indices revealed that N harvest indices remain unaffected due to genotypes and N application schedules, phosphorous harvest indices (PHI) varied with only N application schedules while potassium harvest indices (KHI) varied due to both factors. Genotype HM-4 recorded highest values for nutrient harvest indices while PHI and KHI improved with number of splits (N) from two to four [14].

4. INTERCROPPING LEGUMES

Effective utilization of the available resources *viz*. nutrients, light, space, moisture etc. depends on the space utilized by the individual plants. Biomass production is closely related to the output as yield indicates the quantum of resources captured. Intercropping systems utilizes resources more efficiently than sole crop and suppresses weeds by limited access and restricting their photosynthetic active radiation. Initial slow growth of winter baby corn facilitates successful intercropping with legumes (chickpea, pea, groundnut and lentil). Starter dose of N (20 kg/ha) applied to legumes and baby corn uniformly and remaining recommended dose of nitrogen (RDN) as band placement at critical stages to baby corn. Lowest weed density and biomass observed in additive series system 2:2 than 2:1 and sole baby corn [15]. Yields of rainy season baby corn found unaffected due to intercrops fenugreek (green) and fodder cowpea. Additional income may be earned without affecting the yield of main crop provided the intercrop is of short stature, non bushy, non-competitive and short duration [7].

A cereal-legume intercropping system improves overall productivity, profitability, land use efficiency, crop protection, and soil fertility and reduces soil erosion. Growing legumes as sole crop is not an efficient way for utilization of soil N since legumes itself covers major part of N available by N_2-fixation. Cereals are more competitive to capture soil inorganic N in a cereal-legume intercropping thus forces legumes to depend on N_2-fixation. Intercropping of cereal-legume plays pivotal role in atmospheric N_2-fixation. Baby corn intercropped with legumes (soybean, green gram, black gram and groundnut) found efficient than sole crops of legume species. Highest baby corn equivalent yield obtained under baby corn-groundnut intercropping system. Intercropping brought significant improvement in N_2-fixation by higher number of nodules and their dry weight over sole crops. Greater root length of legumes recorded in intercropping with baby corn. Results suggest that baby corn-legume intercropping (especially groundnut) in 2:1 or 2:2 additive series enhances N-fixing ability of the system and total system productivity [16]. Such intercropping systems may be attempted on rotational basis for fertility management, cultural weed control and diversification of the baby corn production systems.

5. NITROGEN FERTILIZATION

Rate, time and method of N application exerts varied effect on growth of plant. Requirement of N varies with season and as per growth stages within the season. Supply of N less than optimum reduces plant growth and yield depends upon the extent of N deficiency. The N supply in critical optimum quantity is required for maximum harvest. Nitrogen application exceeding than optimum has no yield advantage. Modern approaches for improvement in NUE of baby corn need optimization and efficient utilization of N by coinciding with critical growth stages. Method of N placement is important for its effective utilization. Pre-plant surface application either as broadcast or band placement leads to poor N recovery due to increase in losses. Application of N near to peak demand and distributed into required number of splits reduce losses and helps in effective utilization. Placement of N fertilizer below or side to the seed are effective keeping some distance to avoid any salt injury. In-season surface band applications followed by incorporation by intercultural operations or side dressing are popular and effective methods during early stages of crop. Maize is considered nitro-positive, needs enough N applied by an appropriate technique for most efficient utilization. Side dressing of entire N in three equal splits found superior than side dressing entire quantity at sowing, two splits, broadcasting and, combination of side dressing and broadcasting method [17].

Application of 120 kg N/ha in three splits produces higher marketable yield and net return of rainy season baby corn [18]. Similar response for growth and yield noticed however, green and dry fodder yield, and net return enhanced up to 180 kg N/ha [19]. Scheduling RDN in 3 splits (½ basal, ¼ 25 DAS and ¼ 45 DAS) found superior over two and enhanced green cob yield and quality parameters (starch % and protein %) of winter baby corn. Timing of N application failed to affect vitamin A and C content. Nitrogen applied in three splits provided continuous supply to the crop for longer period over two [20]. Winter crop is more productive with extended duration (45%) than wet season thus requires higher levels of fertilizer application [21].

Harvest of first baby cob gives rise to new female inflorescence and the second cob may be harvested as green/mature cob. This approach attempted by few workers ensuing flexibility after first harvest and hypothesized that combined product may be more beneficial. Response to N application and levels varied with the production systems *viz.* baby corn, green cob, mature cob, baby corn + green cob and baby corn + mature cob during dry season. Harvest of total economic produce as baby corn was more productive than first picking as baby corn and second as green / mature cob. Profitability index was higher for baby corn with application of 160 kg N/ha while for mature cob it was 80 kg/ha. Nitrogen interacted with the production system only when all the cobs were harvested as baby corn thus provided higher yields [22].

6. INTEGRATED NUTRIENT MANAGEMENT

Tropical soils are poor in organic carbon and inherent fertility and management of the soil organic carbon is the most challenging task. Stability of the agricultural production systems are questioned because of imbalance fertilizer use, continued nutrient mining, multiple nutrient deficiencies, depletion of soil organic carbon, and reduction in soil fertility consequently resulting poor soil health and decline in factor productivity. Adverse effects on soil health may be checked or improved by reduced dependency on fertilizers and supplementing part of nutrient requirement through organic sources [23]. Long term sustainability depends on judicious use of nutrients from various available sources. Integrated nutrient management is a widely accepted technique follows judicious use of fertilizers, organic manures, green manure and bio-fertilizers. Such practice reduces cost of cultivation, improves economic gain and increases availability of soil nutrients and beneficial microorganism. Inorganic fertilizers still are the principle means to ensure soil productivity however; carry over effect of fertilizers may be minimized by its low use. Partial substitution of 25% RDN as FYM enhances baby corn yields, quality (sugar, starch, carbohydrate and protein content), NPK content and uptake. Higher substitution (50% RDN) causes significant reduction in yields. The slow release pattern of nutrients from FYM might be the reason. Greater proportion of N as FYM reduces net returns and benefit: cost ratio compare to sole use of inorganic fertilizer sources [24].

Combined use of inorganic, organic and biofertilizer plays an important role because of their synergetic effect. Fertilizer N helps in the promotion of early growth while organic sources improve growth during later phases. Higher uses of synthetic fertilizers reduce biochemical soil activities but in combination to vermicompost enhance baby cob and green fodder yield and build up soil organic carbon, soil fertility, cation exchange capacity, microbial and enzyme activities. Organic sources maintain nutrients availability in rhizosphere by solubilisation effect due to organic acid produced from decay of organic matter hence increases uptake and quality [23]. Incorporation of organic manures immediate after addition leads efficient utilization and reduces losses. The extent of N loss increases with the wait period between manure broadcast and incorporation. Biofertlizers enhances availability of native nutrients, nutrient use efficiency and soil health. Use of biofertilizers (*Azospirillum*/AMF/*Azospirillum* + AMF) enhances chlorophyll 'a' and 'b' and co-inoculation (*Azospirillum* + AMF) improves root length (35%) and root dry weight (47%) over un-inoculated plants. Yield gain in co-inoculation gradually reduces with increase in the levels of inorganic fertilizers (NPK) indicate that influence of biofertilizers also lowered down. Inoculation of AMF or *Azospirillum* enhances baby corn yield and nutrient uptake by 15-25% while the extent of gain increases to 35% with co-inoculation. Drastic reduction in fertilizer response doses observed due to co-inoculation. Agronomic use efficiency, partial factor productivity, apparent recovery of nutrients (NPK) and residual soil fertility considerably increased when co-inoculation combined with lower doses of inorganic fertilizers. Combined use of biofertilizers augment overall effect on crop than their alone application. Integration of biofertilizers seems a viable option to save chemical fertilizers with optimum yield, and profits [25]. Therefore, it is imperative to use these microorganisms either alone or in combination for their synergistic effects. Maintenance of soil health will largely depend on the success of INM strategies in field crops. Benefits of INM are well established but popularization of this technique had to be taken as a core strategy to enhance adoption among the farmers unless it becomes a common technique. Input availability constraints and bottlenecks in adoption be identified and solved [26]. Economic stability of INM is important since chemical fertilizers are required in less quantity and often prove cheaper than organic nutrient sources.

7. FOLIAR FERTILIZATION

Soil application of nutrients at critical stages of crop nutrient requirement is a common method. Usually entire N is applied in 2/3 splits at critical growth stages. Several workers advocated benefits of N supplementation to cereals via foliage by spray of urea solution. Foliar fertilization reduces N loss by leaching and denitrification though losses may occur to soil or atmosphere. Foliar fertilization may be an effective way under dry conditions (impaired root activity), late application and uptake to enhance N content in economic part. However if not properly used, foliar urea sprays adversely affect crop productivity because of urea toxicity, leaf cells desiccation, biuret pollution and disturbance of carbohydrate metabolism. Studies indicate that foliar urea spray increases yields under limited N availability when applied prior to emergence of the flag leaf. Foliar application at reproductive stages *i.e.* anthesis or following two weeks reported to enhance N content of corn grain due to effective N utilization. Benefits may be properly exploited by preventing phytotoxic effect, reduce N losses and understanding its mechanism [27]. The concentration of urea foliar spray and its application timing seems most important in determining the extent of benefit. Basal application of N (138 kg/ha) based on soil test followed by foliar application (3%) at tasseling improved yield by 62.1 per cent than control while higher concentrations (5 and 7 %) were not useful [28]. Foliar fertilization is an effective and economic way to supplement soil applications and correct nutrient deficiencies if diagnosed correctly. Success of foliar fertilization depends on concentration of nutrient, day temperature, fertilizer solubility, wind, rains and requires higher leaf area for effective absorption of nutrient solution. Macronutrients (N) in large quantities cannot be supplied through foliar applications. Hence, it is not a substitute to soil application but a management strategy to supplement soil fertilization in a short time. Foliar fertilization close to anthesis increases grain protein content in food crops. Older plants can tolerate higher concentrations than younger ones [29]. Soil applied N followed by urea foliar sprays (1.5%) at 30, 45 and 60 DAS significantly enhanced growth, yield attributes, yields, nutrients content and uptake by maize cultivars than addition of entire RDN to soil. Significant variations among varieties noted due to interaction between varieties and urea foliar spray [30].

8. RECENT APPROACHES

[31] proposed an imperative N-management schedule by combining soil application followed by foliar at harvest stage of winter baby corn. Ninety five per cent RDN (150 kg/ha) was applied to soil in three splits (50% basal, 25% at knee height stage, 20% at tassel emergence) and remaining 5% RDN as urea foliar spray (3%) just after first picking improved yield attributes, yield, N content and uptake, protein content and profitability irrespective of the genotypes. Foliar application of N close to sink under favourable environmental conditions prevailed during winters with prolonged harvest period facilitated effective utilization. Information's on such aspects are scare and stress to rethink N-management for efficient utilization by baby corn. Small fraction of RDN and its application timing plays an important role in augmenting yields and quality of winter baby corn. Study confirmed usefulness of combined approach in N-management though more studies required under diverse agro-climatic conditions [14].

Several approaches used to determine N-management are either based on judgement of soil or crop N status. These methods are either prescriptive (fixed recommendations) or corrective (in-season) in nature. In-season N-management often proved superior to pre-fixed recommendations since offer demand driven adjustment and are not static (Table 1).

Table 1. Nitrogen optimizing techniques

Possible Technologies	Type	Key Features

1. Blanket/ uniform N application	Field trials based recommendations for fixed dose and time interval	Large area specific recommendations, field is over/under fertilized, yield and profitability response not certain due to varied soil N status, usually poor NUE
2. Soil test based recommendation	Based on soil test calibrations applied at fixed time interval	Representative sample is crucial, usually applied in 3 splits
3. Soil + foliar application	Soil N application in 3 splits (95% RDN) followed by 3% urea foliar spray (5% RDN)	For winter baby corn, applied just after first picking, verification under diverse conditions required
4. Foliar application	Urea used in variable concentrations and application timings	Used for in-season correction of N deficiency
5. Fertigation	Use drip fertigation system with water soluble fertilizers, other irrigation methods reduces NUE	Higher water and NUE, reduces field operations
6. Grid sampling	Grid based soil sampling for spatial distribution of soil test N and mapping	As per N recommendation map variable rate applicator used, complex method
7. Profile NO_3^- N based	Preplant sampling for spatial distribution of NO_3^- N	Suited to dryland areas as leaching losses increase in humid regions
8. Soil management zones	Delineated on the basis of spatial data on soil type, colour, EC, slope, previous year's yield maps, remote sensing etc.	Less consistent since depend on static sources
9. Passive hyper spectral canopy spectrometers	Based on spectral reflectance, Indicates biomass and colour (NDVI) correlated with N uptake	Depends on sunlight thus influenced by light conditions, expansive
10. Active optical sensor	--do--	Own energy source, not influenced by light conditions
11. Chlorophyll meters	Measures chlorophyll content via light reflectance of canopy	Based on tissue N, time consuming, not fit for large area applications
12. LCC	Based on leaf colour intensity match	Very low cost and user's friendly

The emerging approach of site specific nutrient management (SSNM) offers precise management of the production inputs. Hence, provides an opportunity for the variable rate N application over conventional practice of uniform N-management. Timely and precise N application can be done as per variability of fields or within the field. This attractive approach improves NUE, profitability and reduces environmental impact. During initial growth phase of three weeks after emergence, maize plant utilizes lesser soil inorganic N (< 0.5 kg/ha/day). After that rapid increase in N uptake found till tasseling stage with an average uptake of 3.7 to a maximum peak of 6 kg/ha/day. Therefore, pre-plant/basal N application in higher quantities increases the risk and opportunity time for N loss [32]. Of N management strategies *viz.* uniform N rate, grid based, site specific management zone based variable rate N application with constant and variable yield goal used in the recent past. Among these, site specific management zone with variable yield goal found best. Management zone strategy decreased average N application to the extent of 6.3-46.1%. However, several constraints like small holdings, high cost, data base, technical expertise, farmer's perception etc. restrict adoption of precision techniques in India [33]. Temporal and spatial variability in soil N status may be addressed by SSNM strategy (N variable rate technology). Assessment at farmers maize fields indicated that existing recommendations for spatial N application are inappropriate for several sites. Improved recommendation algorithms may be combined with remote sensing methods for early detection of crop N status appropriately timed and spatially arranged supplemental fertilizer application to optimize NUE. Development of specific recommendation equations is necessary for major soils and agro-ecological zones for substantial increase in the NUE [34].

Development of recommendation for side dressing of N has to be based on real time diagnosis of crop N status. Nitrogen concentration in plant reduces with enhancement in the above ground plant biomass (AGPB); a reliable indicator for crop N status is termed as nitrogen nutrition index (NNI). The NNI diagnoses N nutritional status of crop utilizing the ratio of actual plant N concentration compared to critical plant N concentration. The decrease in the plant N concentration with improvement in AGPB is described with the help of a critical N dilution curve [35]. The NNI value ≤ 0.9 represent N deficient status, NNI > 0.9 to ≤ 1.1 indicates optimal N and NNI > 1.1 is N surplus [36]. Destructive sampling followed by chemical analysis and calculation of NNI is not practicable for in-season N-management. Estimation of crop NNI by remote sensing technologies is promising approach by use of chlorophyll meter, passive hyper spectral canopy spectrometers and active optical sensors. These may be used in rice, wheat and maize. Vegetation indices used to measure NNI non-destructively to judge in-season N status of maize. Estimation of AGPB and plant N concentration with handheld active optical sensor and then calculation of NNI is better than direct estimation of NNI by use of spectral indices [35]. Further studies needed for comparison of handheld sensor methods with satellite imagery for estimation of NNI under diverse farm situations and to develop N recommendation algorithms.

[37] compared blanket N application (150 kg/ha in 3 splits) with 50% N as basal (75 kg/ha) followed by top dressing based on Soil Plant Analysis Development (SPAD) value ≤ 45 (each time N @ 20 kg/ha) in summer baby corn. Comparable yield obtained with SPAD based N-management, saved 22 kg N/ha resulted economic gain and improvement in the factor productivity. Precision tools may answer timing and quantity of nitrogenous fertilizers in synchronization with crop need to harvest maximum threshold yield with reduced harm to environment. Leaf colour chart (LCC) a simple, cost effective and user's friendly gadget can be easily used by small holders to determine the N requirement of plant. A six panel plastic chart contains variable green colour shades of increasing intensity facilitate N application as per crop need. [38] evaluated simple handheld tools for in-season N-management in winter sweet corn. Study suggests to replace blanket application of RDN (150 kg/ha) with better tools *i.e.* threshold value of LCC-5 (40% N saving) or active optical sensor based normalized difference vegetation index (NDVI) 0.8 for need based management (20% N saving). Assessment of soil N status revealed net loss in treatments *viz.* control, RDN in 2/3 splits, 50% basal followed by three foliar sprays of urea (2%) and SPAD threshold value 40 and 50. Nitrogen removal by crop, actual balance and net gain were larger in precision N-management techniques (LCC-5 and NDVI 0.8). Nitrogen balance is a reliable parameter used to judge the sustainability and indicates proper soil fertility management.

9. FUTURE STRATEGY AND THRUSTS

Systematic efforts needed for development of specific baby corn genotypes with desired morphological and quality traits. Evaluation of existing maize cultivars required agro-ecological zone wise for their suitability to baby corn production.

To find out baby corn based cropping system options for rainfed and irrigated ecosystems. Baby corn-legume intercropping systems may be identified with enhanced N-fixing ability.

Development of location specific and cost effective INM practices for reduced dependency on chemical fertilizers. Co-inoculation of suitable microbial consortia for synergism, enhance NUE, efficient use of native nutrient and soil health. Integrated approach may be only answer to address day by day increasing deficiencies of micronutrients.

Combined approach involving soil application of N at critical crop growth stages followed by small quantity of N as urea foliar spray close to sink (at harvest stage) should be tried in winter baby corn under diverse agro climatic conditions.

Cost effective and user's friendly precision gadgets like LCC may be a viable option.

REFERENCES

1. Singh MK, Singh RN, Singh SP. Effect of integrated nutrient management on growth, yield and yield attributes of baby corn (*Zea mays*). Veg Sci. 2009;36:77-79.
2. Cassman KG, Dobermann A, Walters DT. Agrosystems, nitrogen use efficiency and nitrogen management. Ambio. 2002;31(2):132-140.
3. Shanahan JF, Kitchen NR, Raun WR, Schepers JS. Responsive in-season nitrogen management for cereals. Comput Electron Agric. 2008;61:51-62.
4. Kumar R, Kumawat N, Kumar S, Singh AK, Bohra JS. Effect of NPKS and Zn fertilization on growth, yield and quality of baby corn-a review. Int J Curr Microbiol Appl Sci. 2017;6(3):1392-1428.
5. Thakur DR, Om Prakash, Kharwara PC, Bhalla SK. Effect of nitrogen and plant spacing on yield, nitrogen uptake and economics in baby corn (*Zea mays*). Indian J Agron. 1998;43(4):668-671.
6. Ramchandrappa BK, Nanjappa HV, Shivkumar HK. Yield and quality of baby corn (*Zea mays* L.) as influenced by spacing and fertilization levels. Acta Agronomica Hung. 2004;52(3):237-243.
7. Rathika S, Velaudham K, Muthukrishnan P, Thavaprakash N. Effect of crop geometry and topping practices on the productivity of baby corn (*Zea mays* L.) based intercropping systems. Madras Agric J. 2008;95(7-12):380-385.
8. Amanullah, Shah P. Timing and rate of nitrogen application influence grain quality and yield in maize planted at high and low densities. J Sci Food Agric. 2010;90:21-29.
9. Lehrsch GA, Sojka RE, Westerman DT. Nitrogen placement, row spacing and furrow irrigation-water positioning effects on corn yield. Agron J. 2000;92:1266-1275.
10. Chauhan SK, Mohan J, Sharma OP, Gadag RN. Analysis of various quality traits in baby corn genotypes. Veg Sci. 2009;36(2):203-208.
11. Hokmalipour S, Darbandi MH. Investgation of nitrogen fertilizer levels on dry matter remobilization of some varieties of corn (*Zea mays* L.). World Appl Sci J. 2011;12(6):862-870.
12. Asaduzzaman M, Biswas M, Islam MN, Rahman MM, Begum R, Sarkar MAR, et al. Variety and N-fertilizer rate influence the growth, yield and yield parameters of baby corn (*Zea mays* L.). J Agric Sci. 2014;6(3):118-131.
13. Hokmalipour S, Shiri-e-Janagard M, Darbandi MH, Peyghami-e-Ashenaee F, Hasanzadeh M, Seiedi MN, et al. Comparision of agronomical nitrogen use efficiency

in three cultivars of corn as affected by nitrogen fertilizer levels. World Appl Sci J. 2010;8(10):1168-1174.

14. Neupane MP, Singh SP, Sravan US, Singh A. Effect of soil and foliar nitrogen application on growth, yield and quality of baby corn cultivars. Journal of Experimental Agriculture International. 2017a;16(3):1-11. DOI: 10.9734/JEAI/2017/32574
15. Sharma RC, Banik P. Babycorn-legumes intercropping system: II weed dynamics and community structure. NJAS-Wagen J Life Sci. 2013;67:11-18.
16. Banik P, Sharma RC. Yield and resource utilization efficiency in baby corn-legume intercropping system in the eastern plateau of India. J Sustain Agr. 2009;33:379-395.
17. Rizwan M, Maqsood M, Rafiq M, Saeed M, Ali, Z. Maize (*Zea mays* L.) response to split application of nitrogen. Int J Agric Biol. 2003;5(1):19-21.
18. Bindhani A, Barik KC, Garnayak LM, Mahapatra PK. Nitrogen management in baby corn (*Zea mays*). Indian J Agron. 2007;52(2):135-138.
19. Dar EA, Harika AS, Datta A, Jat HS. Growth, yield and economic returns from the dual purpose baby corn (*Zea mays*) under different planting geometry and nitrogen levels. Indian J Agron. 2014;59(3):468-470.
20. Muthukumar VB, Velaudham K, Thavaprakash N. Plant growth regulators and split application of nitrogen improves the quality parameters and green cob yield of baby corn (*Zea mays* L.). J Agron. 2007;6(1):208-211.
21. Sahoo SC, Panda MM. Fertilizer requirement of baby corn (*Zea mays*) in wet and winter seasons. Indian J Agric Sci. 1997;67(9):397-398.
22. Silva PSL, Junior BBA, Oliveira VR, Pontes FST, Oliveira OF. Effects of nitrogen application on corn yield after harvesting the apical ear as baby corn. Hortic Bras. 2013;31:419-425.
23. Sharma RC, Banik P. Vermicompost and fertilizer application: effect on productivity and profitability of baby corn (*Zea Mays* L.) and soil health. Compost Sci Util. 2014a;22:83-92.
24. Singh MK, Singh RN, Singh SP, Yadav MK, Singh VK. Integrated nutrient management for higher yield, quality and profitability of baby corn (*Zea mays*). Indian J Agron. 2010;55(2):100-104.
25. Sharma RC, Banik P. Arbuscular mycorrhiza, azospirillum and chemical fertilizers application to baby corn (*Zea mays* L.): Effects on productivity, nutrients use efficiency, economic feasibility and soil fertility. J Plant Nutr. 2014b;37(2):209-223.
26. Singh SP, Shrivastava SK, Kolhe SS, Patel JR, Bargali SS. Prospects of biofertilizers and organic manure utilization: A case study in Durg district. Agric Sci Dig. 2007;27(3):157-161.
27. Gooding MJ, Davies WP. Foliar urea fertilization of cereals: a review. Fert Res. 1992;32:209-222.
28. Sarakhsi HS, Yarnia M, Amirniya R. Effect of nitrogen foliar application in different concentration and growth stage of corn (hybrid-704). Adv Environ Biol. 2010;4(2):291-298.
29. Fageria NK, Barbosa Filho MP, Moreira A, Guimaraes CM. Foliar fertilization of crop plants. J Plant Nutr. 2009;32:1044-1064.
30. Afifi MHM, Khalifa RKM, Camilia YE. Urea foliar application as a partial substitution of soil-applied nitrogen fertilization for some maize cultivars grown in newly cultivated soil. Aust J Basic Appl Sci. 2011;5(7):826-832.
31. Neupane MP, Singh SP, Sravan US. Response of baby corn genotypes to soil and foliar nitrogen application schedule. Arch Agron Soil Sci. 2017b;63(13):1912-1926. DOI: 10.1080/03650340.2017.1311011
32. Sharma LK, Bali SK. A review of methods to improve nitrogen use efficiency in agriculture. Sustainability. 2018;10:51. DOI: 10.3390/su10010051
33. Patil VC. Precision nutrient management: A review. Indian J Agron. 2009;54(2):113-119.

34. Ferguson RB, Hergert GW, Schepers JS, Gotway CA, XCahoon JE, Peterson TA. Site-specific nitrogen management of irrigated maize: yield and soil residual nitrate effects. Soil Sci Soc Am J. 2002;66:544-553.

35. Xia T, Miao Y, Wu D, Shao H, Khosla R, Mi G. Active optical sensing of spring maize for in-season diagnosis of nitrogen status based nitrogen nutrition index. Remote Sens. 2016;8(7):605. DOI: 10.3390/rs8070605.

36. Cilia C, Panigada C, Rossini M, Meroni M, Busetto L, Amaducci S, et al. Nitrogen assessment for variable rate fertilization in maize through hyperspectral imagery. Remote Sens. 2014;6:6549-6565.

37. Kumar S, Maity SK, Singh AK. Effect of the nitrogen management and seed priming with GA3 on the growth and dry matter production of summer maize (*Zea mays*) as baby corn. International Journal of Farm Sciences. 2014;4(3):1-8.

38. Swamy M, Umesh MR, Ananda N, Shanwad UK, Amaregouda A, Manjunath N. Precision nitrogen management for *rabi* sweet corn (*Zea mays* saccharata L.) through decision support tools. Journal of Farm Sciences. 2016;29(1):14-18.