

Nitrogen management in baby corn: A review

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

29 and low organic matter. Maize prefers both ammonium (NH_4^+) and nitrate (NO_3^-) form and
30 nourishing both increases plant growth and yields than NO_3^- alone. The deficiency of N may
31 cause chlorotic condition, yellowing, stunted growth and yield reduction. Nitrogenous
32 fertilizers are conventionally applied in more quantities by the Indian farmers. Generally they
33 apply N based on greenness of the leaf colour, a visual indicator to judge crop N status.
34 Excess application often result N losses, leads to reduction in nitrogen use efficiency (NUE).
35 Plant receives N primarily as inorganic NH_4^+ and NO_3^- ions by roots from rhizosphere.
36 Indigenous soil resources and N applied as fertilizer input both facilitate to form available N
37 pool to plants in a single cropping cycle represent only a small fraction (1-4%) of total soil N.
38 Indigenous supply includes N derived by the crop from inorganic N pool, mineralization of
39 soil organic matter and crop residues, biological N_2 -fixation, atmospheric deposition and
40 irrigation water. Biological N_2 -fixation by legumes and other microorganisms are the second
41 largest source of N input after inorganic N. Low NUE is an issue of great concern in cereal
42 production systems. Spatial and temporal variations are obvious in supply of nutrients from
43 soil and in crop requirement. Several factors *viz.* soil properties, genotype, yield goal are
44 important in deciding nutrient requirement besides other management practices and climatic
45 variations. Added N not utilized by the crop or immobilized organic N from soil pool are
46 vulnerable to loss by leaching, volatilization and denitrification. Hence, NUE of a
47 crop/cropping system may be improved by enhancing the uptake efficiency of applied N and
48 minimizing losses from soil pool [2]. Uniform applications ignore spatial variations in crop
49 demand for N, mismatch between fertilizer N supply and demand, and limitations in
50 accounting of temporal variations and its influence on crop need are the prime reasons
51 responsible for low NUE. Inaccurate applications of fertilizer N in terms of quantity and timing
52 causes poor synchronization. In fact proper synchrony between N supply and demand
53 considering spatial and temporal variations in soil decides the extent of achievable yield,
54 profit and protection to environment [3].

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

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78 **2. PLANT DENSITY × NITROGEN**

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80 Optimum plant population with adequate fertilization are key factors to exploit the full
81 potential of the genotype. Baby corn may be planted at 40 × 20 cm spacing with N 150-200
82 kg/ha to harvest maximum yield. Further increase in plant population enhances operating
83 expenses with reduction in yield and net returns [5]. Growing baby corn at wider spacing (45
84 × 30 cm) significantly enhanced yield attributes and sensory parameters while nutritional
85 parameters were unaffected. Wider spacing with optimum fertilization improves baby corn
86 yield and digestibility of green fodder. Values of nutritional parameters (protein,
87 phosphorous, potassium, calcium and crude fibre content) significantly enhanced except
88 sugars and ascorbic acid from lower levels up to optimum fertilization [6]. Baby cob yield
89 positively influenced and even at same plant population adoption of wider row spacing (75 ×
90 16 cm) proved beneficial than narrow (60 × 20 cm). Keeping wider distance between rows
91 provides better spatial arrangement to individual plants which lead to effective utilization of
92 nutrients, moisture and light. Hence, improve plant height, leaf area index (LAI), total dry
93 matter partitioning with baby cob and fodder yield [7].

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

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107 **3. GENOTYPE × NITROGEN**

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

122 Quality traits of 20 maize genotypes grown as baby corn during rainy and winter
123 seasons showed wide range of variability in morphological and nutritional characteristics.
124 Single cross hybrid HM 4 possessed most desirable morphological and nutritional quality
125 traits while HQPM 1 was next best. Six yield traits viz. husked cob yield/plant, dehusked cob
126 yield/plant, number of cobs/plant, fodder yield/plant, days taken to picking of first and last
127 cob are considered important in elite cultivars for their direct role in baby corn production.
128 Strategic emphasis given to single cross hybrids proved instrumental in raising maize
129 productivity in the recent past. Similar approach may be utilized for baby corn [10]. Maize

130 genotypes differ in efficiency to assimilate total dry matter and the interaction between
131 genotypes and N levels had significant effect on remobilization of total dry matter from plant
132 and stem. An apparent estimation of contribution between anthesis to grain filling indicated
133 varied efficiencies of genotypes in total dry matter remobilization (17.81-22.73%) and total
134 dry matter remobilization from stem (10.09-17.57%) which reduced with increase in the N
135 levels. Enhance N level is related to quantum of photosynthetic surface and is associated to
136 the total sink activity. Yield components and yield significantly increased up to the highest
137 level of N (180 kg/ha) irrespective of genotypes. The best performing genotype produced
138 significantly greater yield over others [11].

139 Genotypes play vital role in determining the yield if other input factors and conditions
140 are kept identical. Yield potential of winter baby corn genotypes differed and cobs/plant and
141 their length were found chief parameters. Genotypes took more time to first silking (85 days),
142 were more productive and significantly enhanced yield up to 160 kg N/ha while those with
143 early silking (71 days) responded only up to 120 kg N/ha. Growth parameters, yield
144 attributes and yield significantly improved up to 160 kg N/ha for two genotypes while it was
145 120 kg/ha for another two genotypes tested. Genotypes vary in their potential to utilize N and
146 respond differently to variable rates of N application. Actually, N is the constituent of protein
147 and nucleic acid hence optimum fertilization promotes plant growth by synthesizing greater
148 protein and chlorophyll and improves plant height, dry matter accumulation, LAI and crop
149 growth rate. Increase in dry matter with N levels indicates that limited N adversely affects dry
150 matter production. Differences observed were larger at later crop stages than early stages
151 [12]. Efficient genotypes respond positively to N application and produce high yield. Nitrogen
152 use efficiency reduces with increase in the levels of N irrespective of genotypes and
153 reductions in efficiencies at high levels are obvious. Selection of an efficient genotype with
154 relatively acceptable NUE reduces wastage of N which otherwise threat to pollute the
155 environment [13].

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

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4. INTERCROPPING LEGUMES

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

182 A cereal-legume intercropping system improves overall productivity, profitability, land use
183 efficiency, crop protection, and soil fertility and reduces soil erosion. Growing legumes as
184 sole crop is not an efficient way for utilization of soil N since legumes itself covers major part
185 of N available by N₂-fixation. Cereals are more competitive to capture soil inorganic N in a
186 cereal-legume intercropping thus forces legumes to depend on N₂-fixation. Intercropping of
187 cereal-legume plays pivotal role in atmospheric N₂-fixation. Baby corn intercropped with
188 legumes (soybean, green gram, black gram and groundnut) found efficient than sole crops of
189 legume species. Highest baby corn equivalent yield obtained under baby corn-groundnut
190 intercropping system. Intercropping brought significant improvement in N₂-fixation by higher
191 number of nodules and their dry weight over sole crops. Greater root length of legumes
192 recorded in intercropping with baby corn. Results suggest that baby corn-legume
193 intercropping (especially groundnut) in 2:1 or 2:2 additive series enhances N-fixing ability of
194 the system and total system productivity [16]. Such intercropping systems may be attempted
195 on rotational basis for fertility management, cultural weed control and diversification of the
196 baby corn production systems.

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198 **5. NITROGEN FERTILIZATION**

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

217 Application of 120 kg N/ha in three splits produces higher marketable yield and net return
218 of rainy season baby corn [18]. Similar response for growth and yield noticed however,
219 green and dry fodder yield, and net return enhanced up to 180 kg N/ha [19]. Scheduling
220 RDN in 3 splits ($\frac{1}{2}$ basal, $\frac{1}{4}$ 25 DAS and $\frac{1}{4}$ 45 DAS) found superior over two and enhanced
221 green cob yield and quality parameters (starch % and protein %) of winter baby corn. Timing
222 of N application failed to affect vitamin A and C content. Nitrogen applied in three splits
223 provided continuous supply to the crop for longer period over two [20]. Winter crop is more
224 productive with extended duration (45%) than wet season thus requires higher levels of
225 fertilizer application [21].

226 Harvest of first baby cob gives rise to new female inflorescence and the second cob may
227 be harvested as green/mature cob. This approach attempted by few workers ensuing
228 flexibility after first harvest and hypothesized that combined product may be more beneficial.
229 Response to N application and levels varied with the production systems viz. baby corn,
230 green cob, mature cob, baby corn + green cob and baby corn + mature cob during dry
231 season. Harvest of total economic produce as baby corn was more productive than first
232 picking as baby corn and second as green / mature cob. Profitability index was higher for
233 baby corn with application of 160 kg N/ha while for mature cob it was 80 kg/ha. Nitrogen

234 interacted with the production system only when all the cobs were harvested as baby corn
235 thus provided higher yields [22].
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237 6. INTEGRATED NUTRIENT MANAGEMENT

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

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258 Combined use of inorganic, organic and biofertilizer plays an important role because of
259 their synergetic effect. Fertilizer N helps in the promotion of early growth while organic
260 sources improve growth during later phases. Higher uses of synthetic fertilizers reduce
261 biochemical soil activities but in combination to vermicompost enhance baby cob and green
262 fodder yield and build up soil organic carbon, soil fertility, cation exchange capacity,
263 microbial and enzyme activities. Organic sources maintain nutrients availability in
264 rhizosphere by solubilisation effect due to organic acid produced from decay of organic
265 matter hence increases uptake and quality [23]. Incorporation of organic manures immediate
266 after addition leads efficient utilization and reduces losses. The extent of N loss increases
267 with the wait period between manure broadcast and incorporation. Biofertilizers enhances
268 availability of native nutrients, nutrient use efficiency and soil health. Use of biofertilizers
269 (*Azospirillum*/AMF/*Azospirillum* + AMF) enhances chlorophyll 'a' and 'b' and co-inoculation
270 (*Azospirillum* + AMF) improves root length (35%) and root dry weight (47%) over un-
271 inoculated plants. Yield gain in co-inoculation gradually reduces with increase in the levels of
272 inorganic fertilizers (NPK) indicate that influence of biofertilizers also lowered down.
273 Inoculation of AMF or *Azospirillum* enhances baby corn yield and nutrient uptake by 15-25%
274 while the extent of gain increases to 35% with co-inoculation. Drastic reduction in fertilizer
275 response doses observed due to co-inoculation. Agronomic use efficiency, partial factor
276 productivity, apparent recovery of nutrients (NPK) and residual soil fertility considerably
277 increased when co-inoculation combined with lower doses of inorganic fertilizers. Combined
278 use of biofertilizers augment overall effect on crop than their alone application. Integration of
279 biofertilizers seems a viable option to save chemical fertilizers with optimum yield, and profits
280 [25]. Therefore, it is imperative to use these microorganisms either alone or in combination
281 for their synergistic effects. Maintenance of soil health will largely depend on the success of
282 INM strategies in field crops. Benefits of INM are well established but popularization of this
283 technique had to be taken as a core strategy to enhance adoption among the farmers unless
284 it becomes a common technique. Input availability constraints and bottlenecks in adoption be
285 identified and solved [26]. Economic stability of INM is important since chemical fertilizers
286 are required in less quantity and often prove cheaper than organic nutrient sources.

287 **7. FOLIAR FERTILIZATION**

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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].

318 **8. RECENT APPROACHES**

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[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].

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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
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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

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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

344 three weeks after emergence, maize plant utilizes lesser soil inorganic N (< 0.5 kg/ha/day).
345 After that rapid increase in N uptake found till tasseling stage with an average uptake of 3.7
346 to a maximum peak of 6 kg/ha/day. Therefore, pre-plant/basal N application in higher
347 quantities increases the risk and opportunity time for N loss [32]. Of N management
348 strategies viz. uniform N rate, grid based, site specific management zone based variable rate
349 N application with constant and variable yield goal used in the recent past. Among these,
350 site specific management zone with variable yield goal found best. Management zone
351 strategy decreased average N application to the extent of 6.3-46.1%. However, several
352 constraints like small holdings, high cost, data base, technical expertise, farmer's perception
353 etc. restrict adoption of precision techniques in India [33]. Temporal and spatial variability in
354 soil N status may be addressed by SSNM strategy (N variable rate technology). Assessment
355 at farmers maize fields indicated that existing recommendations for spatial N application are
356 inappropriate for several sites. Improved recommendation algorithms may be combined with
357 remote sensing methods for early detection of crop N status appropriately timed and
358 spatially arranged supplemental fertilizer application to optimize NUE. Development of
359 specific recommendation equations is necessary for major soils and agro-ecological zones
360 for substantial increase in the NUE [34].

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

378 [37] compared blanket N application (150 kg/ha in 3 splits) with 50% N as basal (75
379 kg/ha) followed by top dressing based on Soil Plant Analysis Development (SPAD) value \leq
380 45 (each time N @ 20 kg/ha) in summer baby corn. Comparable yield obtained with SPAD
381 based N-management, saved 22 kg N/ha resulted economic gain and improvement in the
382 factor productivity. Precision tools may answer timing and quantity of nitrogenous fertilizers
383 in synchronization with crop need to harvest maximum threshold yield with reduced harm to
384 environment. Leaf colour chart (LCC) a simple, cost effective and user's friendly gadget can
385 be easily used by small holders to determine the N requirement of plant. A six panel plastic
386 chart contains variable green colour shades of increasing intensity facilitate N application as
387 per crop need. [38] evaluated simple handheld tools for in-season N-management in winter
388 sweet corn. [39] stated that baby corn is early harvested compare to fresh cop and maturity
389 seed, therefore less nitrogen is applied to baby corn agriculture. Study suggests to replace
390 blanket application of RDN (150 kg/ha) with better tools i.e. threshold value of LCC-5 (40% N
391 saving) or active optical sensor based normalized difference vegetation index (NDVI) 0.8 for
392 need based management (20% N saving). Assessment of soil N status revealed net loss in
393 treatments viz. control, RDN in 2/3 splits, 50% basal followed by three foliar sprays of urea
394 (2%) and SPAD threshold value 40 and 50. Nitrogen removal by crop, actual balance and
395 net gain were larger in precision N-management techniques (LCC-5 and NDVI 0.8). Nitrogen

396 balance is a reliable parameter used to judge the sustainability and indicates proper soil
397 fertility management.

398

399

9. FUTURE STRATEGY AND THRUSTS

400

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

404

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

407

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

412

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

415

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

416

417

418

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