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Foliar supplement of Boron limits yield gaps linked to reproductive growth and development hitches in tomato (*Lycopersicon esculentum*)

Abstract

Bloom drop and small size fruits are fundamental yield-limiting factors widening yield gap in tomato. This study was initiated with the objective to evaluate the contribution of boron combined with NPK in reducing the gap between potential and actual yield in a F1 Cobra 34 tomato hybrid. Treatment combinations consisted of two levels of NPK viz. (20:10:10) and (13:23:13) and three levels of boric acid (H_3BO_3) viz, 0.45mg.L^{-1}, 0.90mg.L^{-1},1.80mg.L^{-1} denoted B1, B2, B3 respectively and an absolute control tested on reproductive growth of tomato. The experiment was an outdoor trial laid out in Randomized Complete Block Design including 3 blocks and7 treatment combinations repeated trice in each block. Same crop management practices were carried out in all experimental units. Parameters evaluated were mean number of flower /truss, mean number of flower drop, mean number of fruits at anthesis, mean number of fruit drop, mean number of fruits that reached harvestable maturity, mature fruit biometric characteristics, mean percentage of fruit cracks and shelf life. Data was analyzed using the SPSS version 17. Results revealed that, combined effect of H_3BO_3 and the two NPKs showed significant variations in all parameters evaluated compared to the control. However, optimum fruit yield related attributes and shelf life were obtained under H_3BO_3 at 1.80 mg.L^{-1} + NPK (13:23:13) treatment.

Keywords: Boric acid, Tomato, Flower to fruit ratio, Fruit yield attributes, Shelf life

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Introduction

Tomato is the most extensively cultivated fruity vegetable in Cameroon. The Western highlands of Cameroon is a hot spot in tomato production out of the 5 agro ecological zones of the country and the Bamenda I municipality is the focal point of tomato production/ supply to the city. Higher yields in the Solanaceae family in which tomato is a member, are initially dependent on the abundance of flowering and the success of pollination and fertilization.[1] This implies that flower buds, flowers and fruit abscission otherwise known as bloom drop is an important yield-limiting factor during the reproductive growth phase in many crops.[2] Many studies accuse edapho-climatic stresses such as heat, water deficit low light conditions as well as failure of pollination/fertilization[3-6] to be important factors that may induce pre and post bloom abscission thus directly interfering in yield. Causes of tomato blossom drop can be grouped into primary and secondary. Primary causes include temperature and relative humidity or cultural (e.g., lack or excess of nitrogen fertility). Secondary causes can include lack of water, reduced or extended light exposure, excessive wind, insect damage, foliar disease, excessive pruning, or heavy fruit set.[7] Naturally, if pollination and or fertilization fail to take place, fruit development stops before anthesis leading to flower and fruit abortion. The most accepted among many hypotheses as to cause of blossom drop, is limited resources to satisfy the demand of several sinks. The findings of[8] suggested three strong points to support the hypothesis that fruit abortion serves to regulate yield, in order to match fruit production to the available resources. The three predictions included: (1) the proportion of initiated fruits which abort is an increasing function of the number of fruits initiated, (2) the number of fruits that reach maturity is an increasing function of resources available to support fruits, (3) on any inflorescence, fruits initiated early have a lower probability of aborting than fruits initiated later.

In a survey carried out among 50 experienced tomato farmers in the Bamenda I municipality of the North West Region of Cameroon, lower yields are associated to intense flower and fruit drop. Previous studies in crop physiology have revealed that Boron is one of the most important micronutrients controlling flowering and fruit setting.[9-11] Soil Phosphorus limits plant growth due to its poor mobility. The situation is further made worse in tropical andosols reported to be poor in phosphorus.[12] There is a strong need to apply large amounts of inorganic Phosphorus fertilizers in agricultural ecosystems as an approach to overcoming P deficiency.[13] Nutrient analysis from10 different soil samples in the study area revealed a mean boron concentration of 0.15ppm. A perusal of literature showed that boron concentration of 0.155pp in tomato production systems means the soil is boron deficient. It was in a bit to seek answers to this problem that this study was initiated with the general aim to reduce yield gaps linked to reproductive growth hitches expressed thru blossom drop. Specifically the influence of combining boron and NPK was investigated. This study was carried out in compliance with existing literature on the promoting role of boric acid and phosphorus in reproductive growth in many flowering plants.

Materials and methods

This study was carried out at Mendankwe village located in the Bamenda I municipality, specifically located at zone III of the Western Highlands agro ecological zone of Cameroon. It has as geographical coordinates 5° 59'0'' North, 10°15'0'' East, with an altitude of 1558 m above sea level. This area has mean annual temperature range of 13-18 °C, characterized by annual rainfalls of about 2230 mm and average humidity of 70 % and 52% in the rainy season and dry season respectively.

Nursery

A month before the start of the field work, 10g of F1 Cobra 34 tomato seeds, produced by TECHNISEM France were nursed in rows at a depth of 3cm on an initially solarized seed bed ploughed to find tilt. A combination of 2:2:1:1 ratio of black garden soil, poultry manure, sand and saw dust respectively were homogenously mixed to constitute the substrate of the seed bed. Sevin 85SP with a.i Carbaryl (1-naphthyl N-methylcarbamate) was applied around the seedbed as precautionary measures against ants and cutworms. A shade was provided over the seedbed to protect the young seedlings from the scorching sunshine or heavy rain. After germination, Dithane M-45 was sprayed on the seedbeds at the rate of 2g/l to protect the seedlings from damping-off. Weeding, mulching, and water management were done as need arose. No chemical fertilizer was used in the seedbed. After 30 days in the nursery, seedlings were hardened for a period of 7days and only robust seedlings of relatively same vegetative growth stage were selected for transplanting.

Experimental design and field layout

The experimental design was a randomized complete block design, composed of seven (7) treatments and four (4) replicates i.e. each block (replicate) had seven experimental units and each experimental unit measured 2mx2m. Each replicate was separated from the others by alleys of 0.5m, and the total plot size of 160m^2 with planting at inter distance of 40cm by 40cm was used. At this interplant distance, each experimental unit had 20 plants. Robust seedlings were transplanted according to the experimental design after 7days of hardening.

Prior to the start of the experiment, top soil at 15cm depth was randomly collected in 10 different spots and analyzed at the soil analysis laboratory of the Faculty of Agronomy and Agricultural sciences of the University of Dschang Cameroon. The soil test was aimed at determining the soil boron concentration in the study site so as to guide the dosage of boric acid to be applied.

Three concentrations of Boric acid (B), viz.0.45mg.L^{-1}, 0.9mg.L^{-1}, 1.8mg.L^{-1} = denoted B1 B2 and B3 respectively were prepared based on the results of soil analysis which indicated a boric concentration of 0.15ppm.The two macro nutrient fertilizers namely NPK 20:10:10 and NPK 13:24:13 which were to be incorporated with boric acid were bought from the local farmers shops. In a whole 7 treatments were administered to their respective plot in the field layout.

The 7 treatments were

T0 – Control

T1- B1+ NPK (20:10:10)

T2- B2+NPK (20:10:10)

T3- B3+NPK (20:10:10)

T4- B1+NPK (13:23:13)

T5- B2+NPK (13:23:13)

T6-B3+ NPK (13:23:13)

Both NPK 20:10:10 and NPK 13:23:13 were applied to their respective plots by spotting at a rate of 25g/plant 14 DAT and just before flowering, specifically 6weeks after treatment (WAT). Foliar spray of boric acid was done 4WAT and the second dose at 6WAT. Other intercultural practices like weeding, pest and disease control, pruning and staking were all done as need arose.

Data description and collection

Eight plants were selected randomly from each unit plot for data collection in such a way that the border effect was avoided. Parameters evaluated were mean number of flower /trusses, mean number of flower drop, mean number of fruits at anthesis, mean number of fruit drop, mean number of fruits that reached maturity all collected cumulative counting. For mature fruit biometric characteristics, fruits were first grouped into 3 grades. Any fruit with length ≥55mm and diameter ≥50mm was considered large, medium size fruits were of length 55≥50mm and diameter 50≥40mm while small size fruits had as length ≤45mm and diameter ≤40mm. From each fruit grade10 randomly selected fruits were used to assess biometric parameters. Mean fruit length and diameter was taken using electronic Vernier calipers, while an electronic scale was used to assess the mean weight of the 10 fruits from each grade. Meantimemean fruit crack/plant were counted and expressed in percentage while shelf life of fruits was evaluated at ambient temperature of 25-30^{0}C. To assess shelf life, 5 fruits harvested at yellow stage of ripening were placed on a jute bag under shade and level of rotting evaluated after 14 days.

Data collected was analyzed using the statistical pack for social science (SPSS) version 17. Treatment means were separated using the Least Significant Difference at P<0.05.

Results and discussion

Although the role of boron in plant growth and development has been reported in several scientific findings, growers of tomatoes have for long and persistently refuse to recognize[14] and incorporate this micronutrient in their production programs. This assertion was clearly observed in the present study as it was noticed during the survey that 100% of tomato growers apply only macronutrients, specifically NPK 20:10:10 with no idea about micronutrient.

Boron and Zinc are essential micronutrients in emerging vegetable-based crop rotation[15] hence their deficiencies are undoubtedly becoming major limiting factors for normal growth and development of fruit crops given that they affect metabolic pathways involved in shoot growth, fruit set and quality, as well as mineral and nutritional status of fruits.[16,17] Soil analysis of the study area indicated a boron concentration of 0.15ppm only (Table 1). This concentration appears to be low and cannot satisfy the crop demand both at vegetative and reproductive growth stages. In the present research all treatments that received boron recorded significantly higher scores in all parameters assessed compared to the control probably due to B supplement. Best results in all parameters assessed were noticed at B concentration of 1.80mg.L^{-1} meaning that this concentration adds to the existing 0.15ppmoptimizes vegetative and reproductive growth of tomato. In a related study[18] found foliar application of Boron at concentration of 1.9mgL^{-1} to optimize plant growth and photosynthetic indices in tomato. This could be attributed to the involvement of boron in both structural and functional physiological biochemistry in plant development. From a physiological point of view, boron application increase chlorophyll a, b and carotenoids content in tomato leaves more than twice compared to same crop grown under boron deficient substrate, hence boron appreciably increase net photosynthetic rate.[18]

Mean number of flowers per cluster

Significant variations were noticed in mean number of flowers/truss, with trials under Boron combined with NPK 13:23:13 scoring the maximum (Figure 1). Significantly higher mean number of flowers per cluster observed in treatment combination of boric acid and NPK

(13:23:13) compared to the combination of boric acid and NPK (20:10:10) might be due to optimum supply of phosphorus. The optimum supply of boron stimulates the uptake of phosphorus by plant roots and might have promoted more flower formation, as phosphorus directly promotes flowering.[19] This result seemly indicates that NPK with high phosphorus concentration enhances number of flowers per cluster. This is in line with the works of[20] who obtained highest number of flower clusters per plant and the earliest picking period and fruit setting with high levels of phosphorus.

Table 1 Soil analysis results

Sample code	Results
Sand	69.5
Silt	10
Clay	30.5
Texture	SSC
Soil reaction	
Ph-H2O (1:2,5)	5.3
Ph-H2O (1:2,5)	4.4
Organic matter	
Organic carbon	5.66
Organic matter	9.76
Total N (g/kg)	2.254
Rapport C/N	25.11
Exchangeable cations in milliequivalents per 100g	
Calcium	8.4
Magnesium	0.56
Potassium	2.32
Sodium	0.023
Boron (ppm)	0.15
Sum of bases	11.31
Cation exchange capacity in milliequivalents per 100g	
CEC pH7	37.6
V (%)	30.07
Available phosphorus	
Bray 11 (mg/kg)	34.13

Source: Unite de recherché d'Analyse des sols et de chimie de l'Environnement, FASA, Uds, 2021

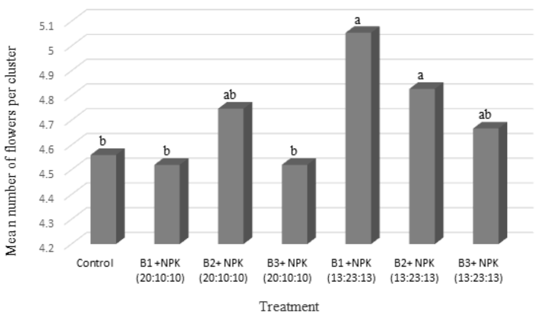

Figure 1 Mean number of flowers per cluster.

*Different letters on histogram show significant differences P<0.05.

Mean number of flower and fruit drop per cluster

Although no significant differences were recorded in mean number of flowers/truss between the control and B1 + NPK 20:10:10 (Figure 1), highly significant differences were however observed between the latter at the level of mean number of flower (Figure 2) and fruit drop / cluster (Figure 3). The highest flower drop of about 50% was noticed in control while highest drop in trials under boron treatments were 20%. Nevertheless, while the concentration of boron increased from B1 to B3 in both NPK 20:10:10 and 13:23:13 respectively, the rate of flower and fruit dropping witnessed a constant decrease. As concerns blossom drop, worse flower and fruit drop (Figures 2&3) scenarios were noticed in the control. This significantly higher number of flower and fruit drop in the control could be attributed to boron deficiency. This result agrees with findings of[21] that Boron deficiency causes a reduction in fruit set, small "shot berries", flower and fruit cluster necrosis and have a drastic effect on fruit quality and yield in grapes. Parthenocarpic fruit development is associated with deficiency in essential micronutrients such as B and Zn.[22] Boron is involved in the structural and functional integrity of the cell wall and membranes, ion fluxes (H^+, K^+, PO_4^{3-}, Rb^+, Ca^{2+}) across the membranes, cell division and elongation, nitrogen and carbohydrate metabolism, sugar transport, cytoskeletal proteins, and plasmalemma-bound enzymes, nucleic acid, indoleacetic acid, polyamines, ascorbic acid, and phenol metabolism and transport[16]. In tomato, seed and fruit formation is limited by failure of pollen production or pollination,[23] Significantly higher number of fruits set per truss in treatments containing boron and at increasing levels of boric acid compared to the control in this study could be attributed to greater production of pollen grains, pollen germination and pollen tube elongation.[24] Improvement in pollen tube development has been proven to be influenced in culture media rich in boric acid.[25]

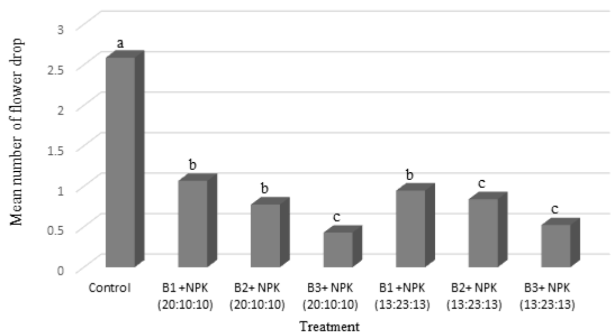

Figure 2 Mean number of flower drop.

*Different letters on histogram show significant differences P<0.05.

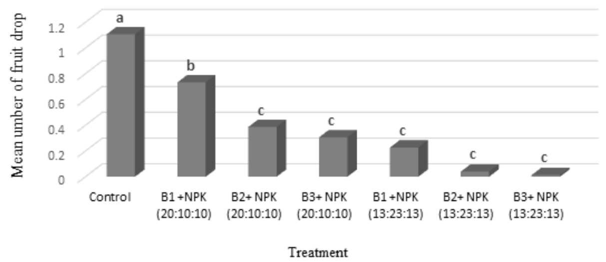

Figure 3 Mean number of fruit drop after anthesis.

*Different letters on histogram show significant differences P<0.05.

Mean number of fruits that attained harvesting maturity per cluster

Highly significant differences were recorded for the number of fruits that reached harvesting maturity. At least 4 fruits per truss got to harvesting maturity in plants treated with different concentrations of boron in combination with NPK 20:10:10 and 13:23:13 compared to the control where at most 2 fruits successfully traversed flower blooming through fruit developmental stages to harvesting maturity per truss (Figure 4). However better results were obtained at B2 and B3 combined with both NPK. Inadequate pollination in many crops has consequences like sub-optimal quantity and quality fruit yields due to low fruit set. Since boron levels influences pollen germination and pollen tube growth, the micronutrient is considered critical for fruit set given that B deficiencies can result in impaired development[26] of the transmitting tissue, preventing fertilization.[27] Increasing Boron concentration in flowers increases initial fruit set, fruit retention, final fruit set or yield of many tree crops.[28] This is the possible reason why in the present study, treatments that received supplement of boron, recorded a significantly higher number of fruits per truss until harvesting maturity (Figure 4).

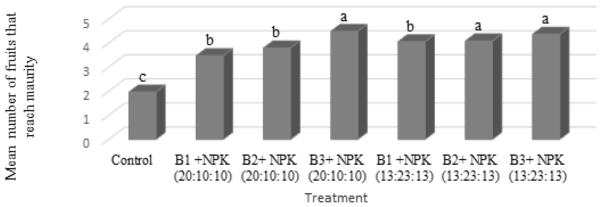

Figure 4 Mean number of fruits that reached maturity/cluster.

*Different letters on histogram show significant differences P<0.05.

Fruit biometric parameters

Among the fruit biometric parameters studied, significant differences were scored between the different boron + NPK treated trials compared to the control in terms of mean fruit length (Figure 5A), diameter (Figure 5B) and weight (Figure 5C) for large, medium and small size fruit grades. The treatment B3 + NPK 13:23:13 scored maximum mean fruit length of 62.7mm, 56.3mm and 33.7mm respectively in large, medium and small fruits while the least measurements measurement of 56.0mm, 46.4mm and 31.7mm were obtained in large, medium and small fruits respectively in the control experiment (Figure 5A). The same trend as observed in diameter (Figure 5B) where treatment B3 + NPK 13:23:13 scored maximum mean fruit length of 58.7mm, 52.9mm and 34.8mm respectively in large, medium and small fruits while the least measurements measurement of 53.0mm, 44.2mm and 32. 0mm were obtained in large, medium and small fruits respectively in the control experiment. The mean weight of the three fruit grades also showed significant variations between the various treatments. In terms of biometric parameters, optimal results in terms of fruit length, diameter and weight were observed in plots that received boron. This could be linked to the fact that Boron is involved in carbohydrate and phenolic metabolism and translocation to meristems, cell division, cell wall construction, and the integrity of the membrane.[29] Besides, better biometric scores were obtained in Boron combination with NPK 13:23:13 compared to the combination with NPK 20:10:10. Recent research has shown that boron does not only play an important role in quality of biometric properties of tomato fruits but also has a great role to play in biosynthesis of natural antioxidants like, Lycopene, Carotene and carotenoid. Lycopene is one of the most important quality indices of tomato, affecting flavor[30] and boron nutrition increases the rate of lycopene compared to tomato grown under boron deficient soils.[18]

Fruits cracks and shelf life

Significant differences were obtained at the level of number of fruit cracks per treatment (Figure 6). At least one cracked fruit was observed/plant in the control experiment while no cracked fruit was recorded in plants treated with boron combined with NPK 20:10:10 and 13:23:13.Plants treated with foliar boric acid had less fruits with concentric and radial cracks as compared to the control (Figure 6) hence also showed a longer shelf life (Figure 7) compared to the control. Comparable results had been obtained by[31] who observed increased cell-wall compactness after boron (B) + calcium (Ca) treatment and the respiration rate was lowest in B + Ca treated tomato fruits at harvest time and during storage. Fruit cuticle composition and their mechanical performance have a special role during ripening because internal pressure is no longer sustained by the degraded cell walls of the pericarp but is directly transmitted to epidermis and cuticle which could eventually crack.[32] No fruit crack observed in trials that received boron supplement (Figure 6) could be attributed to the fact that boron helps maximize maintenance of fruit calcium needed to strengthen fruit membrane and cell wall. This result suggested that B may be important in reducing the incident of fruit cracking. In addition, B may function in cell wall metabolism by maintaining calcium pectate associations in tomatoes.[33]

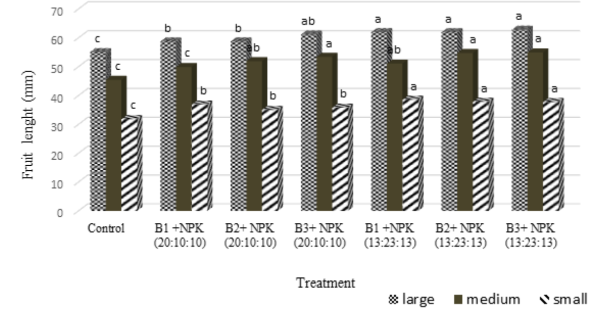

Figure 5A Mean fruit length.

*Different letters on histogram show significant differences P<0.05.

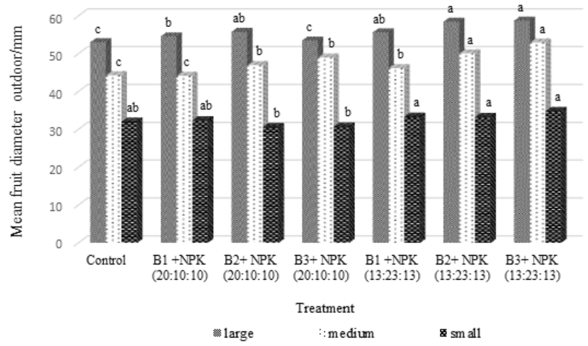

Figure 5B Mean fruit diameter.

*Different letters on histogram show significant differences P<0.05.

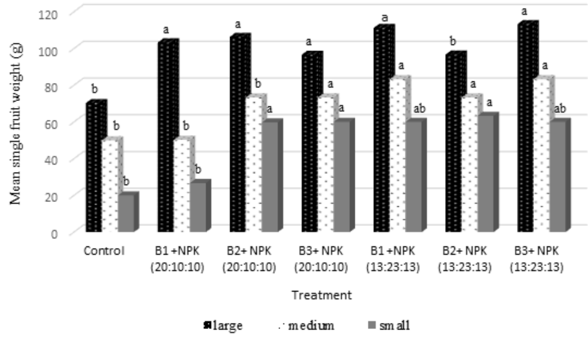

Figure 5c Mean fruit weight.

*Different letters on histogram show significant differences P<0.05.

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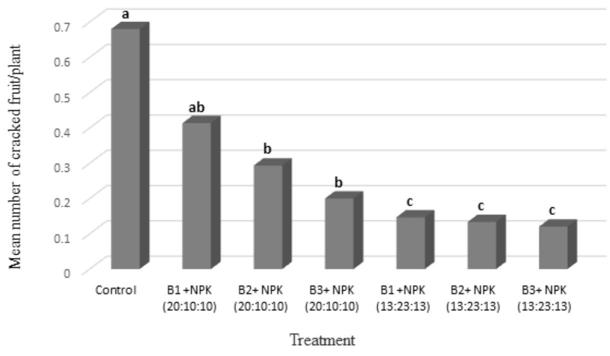

Figure 6 Mean number of fruit cracks/plant.

*Different letters on histogram show significant differences P<0.05.

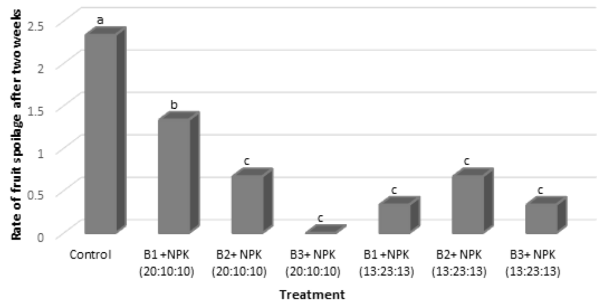

Figure 7 Fruit Shelf life at 14 days after harvest.

Significant differences were also noticed on the degree of spoilage. Fruits harvested from trials in which boron was applied had insignificant level of spoilage, maintaining firmness of skin after 14days under ambient temperature while close to 41% fruits from the control experiment had completely lost firmness within 14days of storage (Figure 7). Both B and Ca play a vital role in cell wall synthesis and structure by cross linking pectin compounds.[34] The ability of B in helping to enhance membranes stability could be the reason B is considered important in reducing the incident of fruit decay (Figure 7).

Conclusion

Tomato yield parameters and storability in the Bamenda I municipality and areas having similar edaphoclimatic conditions could be improved by two pre-bloom foliar applications (4 and 6weeks after transplanting) of boron at 1.8mg/L and NPK 13:23:13 applied at 25g/plant in 2 splits.

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None.

Conflicts of interest

The author declares there is no conflict of interest.

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