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Influence of honey bee attractants in enhancing the seed productivity and quality of onion seed crop

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Abstract
Onion (*Allium cepa* L.) is a commercial crop among bulb crops. It is highly cross-pollinated and depends on various pollinating agents. Therefore the studies were carried out to assess the influence of honey bee attractants in enhancing the productivity and quality of onion seed at Haveli farm, University of Horticultural Sciences, Bagalkot, Karnataka, India during *rabi* season 2017-18. The experiment involves treatments such as, T_1- fennel seed oil (0.5%), T_2- dill seed oil (0.5%), T_3- cumin seed oil (0.5%), T_4- fenugreek seed oil (0.5%), T_5- jaggery solution (10%), T_6- sugar solution (10%) and T_7- control. The onion crop was sprayed with these attractants at 10-15% per cent flowering and during 50 per cent flowering. Among the various treatments imposed, spraying of jaggery solution at 10 per cent (T_5) increased the bee visitations in both first and second spray and was on par with sugar solution at 10% (T_6). The quantitative and qualitative parameters like number of seeds per umbel (19.17), thousand seed weight (3.98 g), seed yield (8.97 q/ha), seed germination (96.67%), seedling length (8.86 cm), vigour index (857) and seedling dry weight (0.022 mg) were significantly higher in seed crop sprayed with jaggery solution at 10 per cent (T_5) compared to other treatments. The results of present investigation conclusively revealed that spraying of jaggery solution at 10 per cent is most economical, feasible and adoptable by the farming community.

Keywords: Onion, attractants, bee visitation, jaggery solution, seed yield

Introduction
The onion (*Allium cepa* L.) is popularly known as the bulb onion or common onion, belongs to the family Alliaceae having chromosome number 2n=16. It is one of the most important commercial crop in India cultivated since more than 5000 years and also in other parts of the world (Thmaburaj and Singh, 2014). The crop is strongly protandrous and largely depends upon insects for cross pollination. The inflorescence is present at the top of the plant and hollow in structure from the inside. The height may vary from 0.9 to 1.2 m depending on the genotype and also the other factors. Flowers in the umbel are enclosed in a membranous two or three white coloured sheath called as spathe. The sheath splits open due to pressure created by growing flowers inside the umbel. There may be 50-2000 florets in an inflorescence depending upon the genotype, planting time, size and storage conditions of the mother bulbs. The perianth segments and stamens are six in two whorls. Whereas, perianth segments were spreading, reflexed free and ovate. Anthers may be bilocular and the colour varies from green or purple depending upon genotype. The ovary is superior and the colour changes with age of flowers. The anther dehiscence takes place between 7:00 and 17:00 hours which is followed by next day with peak between 9:30 and 17:00 hours. The pollen and the stigma receptivity are high on the day of anthesis (Devi *et al*., 2014) [4]. Honeybees are considered as the primary agents for pollination in onion. All the bee species are considered as major pollinators, among them *Apis dorsata* (Fabricius) and *Apis cerana indica* (Fabricius) are most efficient pollinators in onion. Further, the other pollinator's namely syrphid flies, bumble bees, halictid bees, drone flies, butterflies and insects of minor importance are also considered as good pollinators (Devi *et al*., 2015) [5]. Hence, there is a need of insect populations to trip the pollination mechanism and improve the seed set. The bee attractants are influencing worker bees towards potential flowers for pollination and are non toxic and ecofriendly which can be used in organic production of crops. The exogenous substances such as bee attractants bring the metabolite balance of growth and partitioning of assimilate as well as quality and quantity of the seed parameters.

Hence, the study was conducted to assess the best honey bee attractant for enhancing seed yield and quality in onion seed production.

Material and Methods

The present investigation was carried out in *Rabi* season of 2017-18 at Haveli farm, University of Horticultural sciences, Bagalkot. The experiment was laid out in randomized block design (RBD) involving seven treatments in three replications. The treatments are *viz.*, T_1- fennel seed oil (0.5%), T_2- dill seed oil (0.5%), T_3- cumin seed oil (0.5%), T_4- fenugreek seed oil (0.5%), T_5- jaggery solution (10%), T_6- sugar solution (10%) and T_7- control. Between the treatments one meter distance was maintained as a buffer zone. One colony of *A. cerana* was installed at centre of experimental field during flowering for evaluation of bee attractants. Totally two sprays were imposed with different bee attractants during flowering period of the crop, first spray was initiated at 10 per cent flowering and the second spray was carried out at 15 days intervals which coincided 50 per cent of flowering period. From each treatment, five plants were selected in one square meter area randomly and tagged. Observations on number of honeybee spp. and pollinators visiting these plants per minute were recorded between 10:00 am to 12:00 pm and 3:00 pm to 5:00 pm that coincided with their peak foraging activity. Observations were recorded a day before the spray and one, three and five days after each spray. Two observations on visitation of different pollinators were taken in a day. The seed yield and quality parameters such as 1000 seed weight (g), number of seed per umbel (g) and seed yield (q/ha), seed germination (%), seedling length (cm), vigour index and dry weight (mg) were recorded after harvest of umbels. The data obtained from the experiment were first transformed and then subjected to statistical analysis. Further, the treatment efficacy was compared by following Duncan's Multiple Range Test (DMRT) (Sundarrajan *et al*., 1972) [11].

Results and Discussion

Among different treatments evaluated as bee attractants to enhance pollination, seed production, productivity and quality of onion seed. The onion crop sprayed with jaggery solution at 10 per cent (T_5) recorded significantly highest bee visitations of *A. cerana*, *A. dorasta*, *A. florea* and *T. irridipennis* after first and second spray during the experimentation with 3.61, 2.78, 1.88 and 0.85 bees per plant per min, respectively which was at par with sugar solution at 10 per cent (T_6) indicating the superiority of both the treatments in attracting the all the bee species (Table 1, 2, 3 & 4). The next best treatments were fennel seed oil at 0.5 per cent and dill seed oil at 0.5 per cent which were also efficient in attracting more number of bees compared to unsprayed control. The results obtained in the present investigation are in close agreement with Kalmath and Sattigi (2005) [6] who reported that jaggery solution at 10 per cent in onion had phagostimulatory effect which attracted maximum number of pollinators after first and second spray.

Similarly, highest seed yield (8.97 q/ha), number of seeds per umbel (19.1 g) and 1000 seed weight (3.98 g) was registered in jaggery solution at 10 per cent (T_5) (5.10, 19.17, 3.98g and 8.97 q/ha, respectively) which was statistically on par with sugar solution at 10 per cent (T_6) (18.23 g seeds/umbel, 3.98g 1000 seed wt and 8.94 q/ha seed yield, respectively) indicating both the attractants were equally effective in recording higher seed yield parameters (Table 5). Whereas, control (T_7) registered lowest quantitative parameters (7.81 g seeds/umbel, 2.50g 1000 seed wt and 4.58 q/ha ha seed yield, respectively). Similar results were reported in onion by Kalmath and Sattigi (2005) [6]. Similarly, Citral, Cacambe, Bee-Q, Bee scent as bee attractants had phagostimulatory effect in onion were reported by Kalmath and Sattigi (2004) [7], Kulkarni *et al*. (2017) [8]. Even in other crops, Cacambe and jaggery solution which attracted maximum number of pollinators and increased the yield in radish were reported by Chandrashekar (2009) [1] and Wankhede (2017) [13] in pigeon pea.

The qualitative seed parameters like, seed germination (96.67%), seedling length (8.86 cm), seedling vigour index (857) and seedling dry weight (0.022mg) was significantly highest in jaggery solution at 10 per cent (T_5) which was statistically on par with sugar solution at 10 per cent (T_6) (94.46%, 8.82 cm, 833 and 0.019 mg, respectively) indicating that both the attractants were equally effective in recording highest seed quality parameters. The unsprayed treatment control (T_7) recorded significantly lowest seed germination, seedling length seedling vigour index and seedling dry weight (72.33%, 6.39 cm, 463 and 0.010 mg, respectively) (Table 5). Further, the results obtained in the present investigation are close agreement with the results reported in lucerne and pigeon pea by chavan (2013) [3] and Chandravathi and Gurumurthy (2016) [2].

The increased number of *A. cerana indica*, *A. dorasta*, *A. florea*, *T. irridipennis* and other pollinator's visitations were found significantly highest in jaggery solution at 10 per cent. It was mainly due to phagostimulatory effect (Stimulating feeding in pollinators) on the honeybee and other pollinator's and consequently enhancing quantitative and qualitative yield parameters. Because, the average amount of attractants act as nectar and energy for honeybees in onion flower which were positively correlated with the number of bee visitations and caused the well distribution of pollen, thus it resulted in the effective cross pollination and better seed setting. In addition, jaggery solution contained 50 per cent sucrose, 20 per cent invert sugar and 20 per moisture, helped in proper growth and development of honeybees.

Table 1: Influence of bee attractants on visitation of *A. cerana indica* on onion seed crop.

Treatment	Number of bees / plants /min									
	First Spray					Second spray				
	1DBS	1DAS	3DAS	5 DAS	Mean	1DBS	1DAS	3DAS	5 DAS	Mean
T_1 : Fennel seed oil @ 0.5%	0.28 [a] (0.89)	3.78 [b] (2.06)	3.82 [b] (2.08)	3.71 [b] (2.05)	2.89 [b] (1.70)	0.29 [a] (0.89)	3.82 [b] (2.08)	3.88 [b] (2.09)	3.76 [b] (2.06)	2.94 [b] (1.72)
T_2 : Dill seed oil @ 0.5%	0.28 [a] (0.88)	3.66 [b] (2.04)	3.69 [b] (2.04)	3.61 [a] (2.03)	2.81 [b] (1.68)	0.33 [a] (0.91)	3.68 [b] (2.05)	3.74 [b] (2.06)	3.66 [b] (2.04)	2.85 [b] (1.69)
T_3: Cumin seed oil @ 0.5%	0.33 [a] (0.91)	2.92 [c] (1.85)	2.95 [c] (1.86)	2.89 [d] (1.84)	2.28 [c] (1.51)	0.32 [a] (0.55)	2.95 [c] (1.87)	3.01 [c] (1.87)	2.94 [c] (1.85)	2.31 [c] (1.52)
T_4: Fenugreek seed oil @ 0.5%	0.30 [a] (0.89)	2.28 [d] (1.67)	2.33 [d] (1.68)	2.25 [d] (1.66)	1.80 [d] (1.34)	0.30 (0.90)[a]	2.39 [d] (1.70)	2.42 [d] (1.71)	2.30 [d] (1.67)	1.83 [d] (1.36)
T_5: Jaggery solution @ 10%	0.27 [a]	4.70 [a]	4.74 [a]	4.64 [a]	3.59 [a]	0.27	4.72 [a]	4.77 [a]	4.67 [a]	3.61 [a]

	(0.87)	(2.28)	(2.29)	(2.26)	(1.90)	(0.88)[a]	(2.28)	(2.30)	(2.27)	(1.90)
T_6: Sugar solution @ 10%	0.23[a] (0.85)	4.67[a] (2.27)	4.71[a] (2.28)	4.56[a] (2.24)	3.54[a] (1.89)	0.26 (0.87)[a]	4.64[a] (2.27)	4.72 (2.28)[a]	4.59[a] (2.26)	3.56[a] (1.89)
T_7: Control	0.24[a] (0.86)	0.34[e] (0.90)	0.35[e] (0.90)	0.36[e] (0.91)	0.32[e] (0.54)	0.32 (0.90)[a]	0.38[e] (0.92)	0.36[e] (0.91)	0.37[e] (0.91)	0.36[e] (0.59)
S.Em ±	0.04	0.05	0.06	0.05	0.03	0.03	0.05	0.05	0.04	0.04
C.D at 5%	NS	0.17	0.20	0.16	0.09	NS	0.15	0.17	0.12	0.14

DBS- Days before spray DAS-Day after spray
Figures in the parenthesis are √x + 0.5 transformed values
In a column, means followed by same alphabet do not differ significantly (p= 0.05) by DMRT
*Without any bee attractants spray

Table 2: Influence of bee attractants on visitation of *A. dorasta* on onion seed crop.

Treatment	Number of bees / plants /min									
	First Spray					Second spray				
	1DBS	1DAS	3DAS	5 DAS	Mean	1DBS	1DAS	3DAS	5 DAS	Mean
T_1 : Fennel seed oil @ 0.5%	0.30[a] (0.90)	2.80[b] (1.81)	2.86[b] (1.83)	2.73[b] (1.55)	2.18[b] (1.49)	0.30 (0.89)[a]	2.83 (1.82)[b]	2.97[b] (1.86)	2.77 (1.81)[b]	2.22[b] (1.50)
T_2 : Dill seed oil @ 0.5%	0.20[a] (0.88)	2.76[b] (1.80)	2.80[b] (1.82)	2.67[b] (1.53)	2.13 (1.48)[b]	0.23 (0.86)[a]	2.78 (1.81)[b]	2.93[b] (1.85)	2.73[b] (1.80)	2.17[b] (1.49)
T_3: Cumin seed oil @ 0.5%	0.21[a] (0.84)	2.18[c] (1.63)	2.21[c] (1.65)	2.16[c] (1.40)	1.70 (1.32)[c]	0.26 (0.87)[a]	2.19 (1.64)[c]	2.33[c] (1.68)	2.16[c] (1.63)	1.74[c] (1.34)
T_4: Fenugreek seed oil @ 0.5%	0.31[a] (0.90)	1.61[d] (1.45)	1.67[d] (1.48)	1.54[d] (1.26)	1.29[d] (1.16)	0.27 (0.90)[a]	1.63 (1.46)[d]	1.72[d] (1.49)	1.60[d] (1.45)	1.32[d] (1.17)
T_5: Jaggery solution @ 10%	0.21[a] (0.84)	3.62[a] (2.03)	3.66[a] (2.05)	3.53[a] (1.71)	2.77[a] (1.68)	0.20 (0.89)[a]	3.61 (2.03)[a]	3.64 (2.03)[a]	3.57[a] (2.02)	2.78[a] (1.68)
T_6: Sugar solution @ 10%	0.27[a] (0.88)	3.58[a] (2.02)	3.63[a] (2.03)	3.49[a] (1.69)	2.74[a] (1.67)	0.22 (0.90)[a]	3.57 (2.02)[a]	3.61[a] (2.04)	3.53[a] (2.01)	2.76[a] (1.67)
T_7: Control*	0.32[a] (0.90)	0.31[e] (0.89)	0.33[e] (0.90)	0.29[e] (0.64)	0.31[e] (0.59)	0.30 (0.89)[a]	0.35 (0.91)[e]	0.37[e] (0.92)	0.30[e] (0.89)	0.24[e] (0.53)
S.Em ±	0.03	0.03	0.05	0.02	0.05	0.03	0.04	0.05	0.04	0.05
C.D at 5%	NS	0.11	0.15	0.07	0.15	NS	0.14	0.16	0.13	0.17

DBS- Days before spray DAS-Day after spray
Figures in the parenthesis are √x + 0.5 transformed values
In a column, means followed by same alphabet do not differ significantly (p= 0.05) by DMRT
*Without any bee attractants spray

Table 3: Influence of bee attractants on visitation of *A. florea* on onion seed crop.

Treatment	Number of bees / plants /min									
	First Spray					Second spray				
	1DBS	1DAS	3DAS	5 DAS	Mean	1DBS	1DAS	3DAS	5 DAS	Mean
T_1 : Fennel seed oil @ 0.5%	0.31[a] (0.90)	1.87[b] (1.55)	1.93[b] (1.56)	1.80 (1.52)[b]	1.49 (1.22)[b]	0.24 (0.86)[a]	1.93 (1.56)[b]	1.99 (1.58)[b]	1.89 (1.55)[b]	1.53 (1.23)[b]
T_2 : Dill seed oil @ 0.5%	0.34[a] (0.91)	1.88[b] (1.55)	1.90[b] (1.55)	1.77 (1.50)[bc]	1.48 (1.21)[b]	0.37 (0.93)[a]	1.91 (1.55)[b]	1.95 (1.57)[b]	1.86 (1.54)[b]	1.50 (1.24)[b]
T_3: Cumin seed oil @ 0.5%	0.29[a] (0.89)	1.50[c] (1.42)	1.53[c] (1.42)	1.42 (1.38)[cd]	1.18 (1.09)[c]	0.19 (0.83)[a]	1.54 (1.42)[c]	1.58 (1.44)[c]	1.51 (1.41)[c]	1.24 (1.10)[c]
T_4: Fenugreek seed oil @ 0.5%	0.22[a] (0.84)	1.17[d] (1.29)	1.19[d] (1.29)	1.14 (1.28)[d]	0.93 (0.97)[d]	0.25 (0.87)[a]	1.17 (1.29)[d]	1.23 (1.31)[d]	1.14 (1.28)[d]	0.95 (0.97)[d]
T_5: Jaggery solution @ 10%	0.33[a] (0.91)	2.35[a] (1.69)	2.40[a] (1.71)	2.29 (1.67)[a]	1.84 (1.36)[a]	0.27 (0.88)[a]	2.41 (1.70)[a]	2.45 (1.72)[a]	2.38 (1.70)[a]	1.88 (1.37)[a]
T_6: Sugar solution @ 10%	0.37[a] (0.93)	2.31[a] (1.68)	2.38[a] (1.70)	2.22 (1.65)[a]	1.82 (1.35)[a]	0.34 (0.91)[a]	2.39 (1.69)[a]	2.42 (1.71)[a]	2.36 (1.69)[a]	1.84 (1.37)[a]
T_7: Control*	0.23[a] (0.85)	0.25[e] (0.86)	0.25[e] (0.86)	0.26 (0.86)[e]	0.25 (0.47)[e]	0.28 (0.88)[a]	0.24 (0.85)[e]	0.26 (0.86)[e]	0.25 (0.53)[e]	0.25 (0.47)[e]
S.Em ±	0.03	0.03	0.04	0.02	0.04	0.03	0.04	0.05	0.03	0.04
C.D at 5%	NS	0.10	0.14	0.07	0.12	NS	0.13	0.16	0.11	0.14

DBS- Days before spray DAS-Day after spray
Figures in the parenthesis are √x + 0.5 transformed values
In a column, means followed by same alphabet do not differ significantly (p= 0.05) by DMRT
*Without any bee attractants spray

Table 4: Influence of bee attractants on visitation of *T. irridipennis* on onion seed crop.

Treatment	Number of bees / plants /min									
	First Spray					Second spray				
	1DBS	1DAS	3DAS	5 DAS	Mean	1DBS	1DAS	3DAS	5 DAS	Mean
T_1 : Fennel seed oil @ 0.5%	0.22[a] (0.85)	0.68 (1.09)[b]	0.75[b] (1.12)	0.65[b] (1.07)	0.58[b] (0.79)	0.22[a] (0.85)	0.78[b] (1.13)	0.82[b] (1.15)	0.72[b] (1.10)	0.60[b] (0.81)
T_2 : Dill seed oil @ 0.5%	0.26[a]	0.66	0.69[b]	0.64[b]	0.56[b]	0.28[a]	0.71[b]	0.78[b]	0.69[b]	0.58[b]

	(0.87)	(1.08)[b]	(1.09)	(1.07)	(0.78)	(0.88)	(1.10)	(1.13)	(1.09)	(0.80)
T_3: Cumin seed oil @ 0.5%	0.29 [a] (0.89)	0.43 (0.96)[c]	0.50 [c] (1.00)	0.41 [c] (0.94)	0.46 [c] (0.71)	0.27 [a] (0.88)	0.49 [c] (0.99)	0.54 [c] (0.77)	0.47 [c] (0.99)	0.47 [c] (0.72)
T_4: Fenugreek seed oil @ 0.5%	0.25 [a] (0.87)	0.29 (0.89)[cd]	0.32 [d] (0.90)	0.17 [d] (0.82)	0.35 [d] (0.63)	0.32 [a] (0.89)	0.39 [d] (0.89)	0.37 [d] (0.93)	0.27 [d] (0.88)	0.36 [d] (0.64)
T_5: Jaggery solution @ 10%	0.28 [a] (0.88)	1.00 (1.22)[a]	1.05 [a] (1.25)	0.97 [a] (1.21)	0.83 [a] (0.94)	0.30 [a] (0.90)	1.02 [a] (1.24)	1.10 [a] (1.26)	0.99 [a] (1.22)	0.85 [a] 0.95)
T_6: Sugar solution @ 10%	0.26 [a] (0.89)	0.97 (1.21)[a]	1.01 [a] (1.22)	0.95 [a] (1.20)	0.81 [a] (0.93)	0.29 [a] (0.87)	1.00 [a] (1.23)	1.07 [a] (1.25)	0.96 [a] (1.20)	0.82 [a] (0.93)
T_7: Control*	0.19 (0.83)[a]	0.18 (0.82)[d]	0.15 [e] (0.80)	0.19 [d] (0.72)	0.23 [e] (0.52)	0.23 [a] (0.85)	0.16 [e] (0.71)	0.15 [e] (0.69)	0.19 [e] (0.72)	0.21 [e] (0.50)
S.Em ±	0.05	0.02	0.04	0.03	0.03	0.05	0.03	0.05	0.04	0.04
C.D at 5%	NS	0.07	0.14	0.10	0.11	NS	0.11	0.16	0.12	0.14

DBS- Days before spray DAS-Day after spray
Figures in the parenthesis are $\sqrt{x} + 0.5$ transformed values
In a column, means followed by same alphabet do not differ significantly (p= 0.05) by DMRT
*Without any bee attractants spray

Table 5: Influence of bee attractants on seed yield and quality parameters of onion.

Treatments	No. of umbels/plant	No. of seeds/umbel	1000 seed weight (g)	Seed yield (q/ha)	Seed germination (%)	Seedling length (cm)	Seedling vigour index	Seedling dry weight (mg^{-10} seedlings)
T_1 : Fennel seed oil @ 0.5%	4.77 [a] (2.28)	14.20 [b] (3.83)	3.22 [b] (1.93)	7.33 [b] (2.80)	85.90 [b] (68.17)	8.12 [b] (2.94)	697 [b] (26.40)	0.018 [b] (0.12)
T_2 : Dill seed oil @ 0.5%	4.80 [a] (2.30)	13.89 [b] (3.79)	3.17 [b] (1.91)	7.27 [b] (2.78)	85.55 [b] (67.67)	7.95 [b] (2.91)	680[b] (26.09)	0.017 [b] (1.91)
T_3: Cumin seed oil @ 0.5%	4.90 [a] (2.32)	10.25 [c] (3.73)	3.00 [bc] (1.87)	5.80 [c] (2.51)	81.33 [bc] (64.46)	6.97 [c] (2.73)	567 [c] (23.81)	0.017 [c] (1.87)
T_4: Fenugreek seed oil @ 0.5%	4.53 [a] (2.24)	8.43 [d] (3.45)	2.91 [bc] (1.85)	5.33 [cd] (2.45)	80.33 [c] (63.69)	6.50 [d] (2.64)	522 [c] (22.85)	0.015 [d] (1.85)
T_5: Jaggery solution @ 10%	5.10 [a] (2.37)	19.17 [a] (4.44)	3.98 [a] (2.12)	8.97 [a] (3.08)	96.67 [a] (79.50)	8.86 [a] (3.06)	857 [a] (29.28)	0.022 [a] (2.12)
T_6: Sugar solution @ 10%	5. 07 [a] (2.36)	18.23 [a] (3.36)	3.98 [a] (2.11)	8.94 [a] (3.07)	94.46 [a] (76.52)	8.82 [a] (3.05)	833 [a] (28.87)	0.019 [a] (2.11)
T_7: Control*	4.35 [a] (2.19)	7.81 [d] (3.27)	2.50 [c] (1.72)	4.58 [d] (2.24)	72.33 [d] (58.28)	6.39 [d] (2.62)	463 [d] (22.53)	0.010 [d] (2.62)
S. Em ±	0.20	0.11	0.05	0.08	1.30	0.03	0.38	0.001
C.D at 5%	NS	0.33	0.17	0.26	3.94	0.08	1.14	0.003
C.V %	5.14	5.19	5.23	5.49	3.29	1.70	2.57	4.54

Figures in the parenthesis are $\sqrt{x} + 0.5$ transformed values
In a column, means followed by same alphabet do not differ significantly (p= 0.05) by DMRT *without any bee attractant spray

Conclusion

From the foregoing discussion, it can be concluded that spraying of jaggery solution at 10 per cent is best to increase the bee visitations in onion such as, *A. cerana indica*, *A. dorasta*, *A. florea*, *T. irridipennis* and other pollinator's. Hence, jaggery solution at 10 per cent can be considered as one of the most effective and economical attractant in enhancing seed yield and quality of onion crop.

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