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Short Communication

Beta-carotene rich pure line of tomato with yellow-orange fruit colour

Ankur Agarwal*, Om Prakash, SK Dwivedi and Madhu Bala

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Tomato (*Solanum lycopersicum* L.) is the second most consumed vegetable around the world with a production of 159.02 mt from 4.73 mha area (Vanitha et al. 2013). According to FAO, it is a part of healthy and balanced diet with per capita consumption of 19 kg per year. Tomato provides vitamins C and B with minor quantities of E and A, minerals and carotenoids which acts as antioxidants. According to FAO, Vitamin A deficiency is public health problem in >118 countries. Tomatoes have red colour carotenoid, it is not utilized biologically as provitamin-A as is beta-carotene (Barret and Anthon 2001). Considering the importance of tomato in daily human diet of both rich and poor, varieties with higher beta carotene content can help in mitigating the beta-carotene deficiency disorders vis-à-vis in reducing the risk of associated health problems related with growth and reproduction including mortality and morbidity from infectious diseases. For this reason, varieties with high beta-carotene in tomatoes may prove beneficial. Few efforts have been made to develop beta carotene rich tomato variety globally (Stommel 2001). In India, efforts have been made to develop anthocyanin rich tomato varieties through metabolic engineering (Maligeppagol et al. 2013). Although India has vast agro-climatic variability which supports great biological diversity but in case of tomato the genetic base of Indian cultivars is narrow. Garande and Patil (2014) has also emphasized the importance of orange coloured cultivars as a rich source of beta carotene and reported that no commercial cultivar of tomato has been developed in India for enrichment of vitamin A. Therefore, the nutritional importance of tomato necessitates to formulate breeding programme and to develop cultivars rich in antioxidant compounds with good quality and yield. Defence Institute of Bio-Energy Research (DIBER) Haldwani, a premier institute of Defence Research & Development Organization, has made efforts to breed tomato varieties and hybrids for higher yield and cold tolerance (Agarwal et al. 2014, Agarwal et al. 2015, Agarwal et al. 2017). Efforts were also made to develop orange-yellow coloured tomato line with high beta carotene so that supplementation of vitamin A can be enhanced naturally in diet. The institute has been instrumental in developing varieties and hybrids of various vegetable crops since its inception. Few important tomato varieties developed by this institute include DARL-62 (Determinate growth habit, identified for release at State level by State Variety release committee, Uttarakhand during 2005), DARL-64 (Determinate growth habit, identified for release at State level by State Variety release committee, Uttarakhand during 2008), DARL-68 (Indeterminate in

Fig 1: A) Plant of beta carotene rich tomato line-DIBER Sel 1, B) Closer view of mature fruits of beta carotene rich line, C) Variability in tomato fruits colour and shape.

Defence Institute of Bio-Energy Research (DIBER), DRDO, Min. of Defence, Govt. of India, Haldwani, Uttarakhand -263139

*Corresponding author, E-mail: ankurdr@rediffmail.com

Table 1: Qualitative and Quantitative traits of beta carotene rich tomato line DIBER Sel-1

Variety	Growth habit[#]	Leaf type[#]	Fruit shape[#]	Immature Fruit colour[#]	Mature Fruit colour[#]	Average fruit weight (g)	Fruit yield (kg/ plant)	Chlorophyll-a content (mg/100 ml)	Chlorophyll-b content (mg/100 ml)	Beta-carotene content (mg/kg) FW	Lycopene content (mg/kg) FW
DARL-64	Det	Standard	Round	Green	Red	45.52^{a}	1.012^{a}	0.0577^{ab}	0.0941^{ab}	1.501^{a}	37.622^{b}
DARL-66	Det	Standard	Oblong	Green	Red	52.14^{ac}	1.234^{a}	0.0654^{b}	0.1106^{b}	0.844^{ab}	41.294^{a}
CLN 2264 J	Indet	Potato leaf	Heart shaped	Green	Red	80.22^{bc}	1.245^{a}	0.0457^{a}	0.0771^{a}	3.754^{a}	54.283^{a}
CLN 264H	Indet	Standard	Round	Green	Red	100.25^{b}	1.523^{ab}	0.0448^{a}	0.0739^{a}	2.382^{a}	37.922^{ab}
Arka Abha	Det	Standard	High rounded	Green	Red	65.23^{ab}	1.457^{ab}	0.0449^{a}	0.0756^{a}	0.204^{a}	25.492^{ab}
Arka Alok	Det	Standard	Slightly flattened	Green	Red	70.25^{abc}	1.652^{ab}	0.0600^{ab}	0.1019^{ab}	0.437^{a}	54.711^{a}
DIBERSel-1	Det	Standard	High rounded	Green	Orange-yellow	100.52^{b}	2.210^{b}	0.0493^{ab}	0.0829^{ab}	12.142^{b}	7.558^{b}

[#] as per IPGRI, Rome descriptor for tomato; Means followed by the same letters are not significantly different as per Duncan's Multiple Range Test, significance tested at P d" 0.01

habit, identified for release at National level for zone III and IV by AICRP-VC during 2014) and hybrids DARL-304 (Determinate growth habit, identified for release at State level by State Variety Release Committee, Uttarakhand during 2003) and DARL-305 (Determinate growth habit, identified for release at State level by State Variety Release Committee, Uttarakhand during 2011).

The present investigation was carried out at Defence Institute of Bio-Energy Research (DIBER) Haldwani under naturally ventilated polyhouse conditions. The orange-yellow coloured line of tomato was selected from the segregating population arising out of the line CLN 2264 H which is red coloured line. The orange – yellow variant was selected over the generations as pure line selection method and pure line was developed as DIBER Sel-1 with orange–yellow coloured tomato. No segregation has been observed in the line under field conditions. This material was compared with other tomato lines. The experiment comprised of 02 indigenous developed (DARL-64, DARL-66 developed by DIBER), 02 released variety (Arka Abha, Arka Alok developed by IIHR, Bangalore) and 02 exotic lines (CLN2264J, CLN 2264H from AVRDC Taiwan) of tomato. Crop was raised during winter 2015 under polyhouse conditions. Seeds of the germplasm lines were sown in the nursery during last week of the Sep and transplanted in the beds during last week of Oct. Transplanting were done at a spacing of 60 × 45 cm and all recommended cultural practices were followed uniformly to raise healthy crop. Experiments were laid out in RBD with three replications consisting nine plants per plot and data were recorded on five plants randomly. The observations were recorded on leaf type (1=dwarf, 2=potato leaf type, 3=standard, 4=peruvianum, 5=pimpinellifoilium, 6=hirsutum), fruit shape (1=flattened, 2=slightly flattened, 3=rounded, 4=high rounded, 5=heart shaped, 6=long oblong, 7=pyriform, 8=ellipsoid, 9=other), immature fruit colour (1=greenish white, 3=light green, 5=green, 7=dark green, 9=very dark green), mature fruit colour (1=green, 2=yellow, 3=orange, 4=pink, 5=red, 6=other) as per the IPGRI descriptors for tomato. Quantitative traits studied were average fruit weight (g) and fruit yield per plant. Qualitative traits like Chlorophyll a and b content of leaves, lycopene and beta-carotene content of fruits were estimated using method of Nagata and Yamashita (1992) on fresh weight basis. Statistical analysis was carried out as per standard statistical procedures of Duncan Multiple Range Test (DMRT).

The results revealed that newly developed line DIBER Sel-1 has determinate growth habit in contrast to its parental line CLN 2264H which is indeterminate in growth habit (Table 1). Fruit shape of this line is high-rounded as per ISPGR descriptor. Immature fruit colour is green and mature fruit colour is orange- yellow compared to red for rest of the lines under study including the parental line CLN 2264 H. Significant variations were observed among the quantitative traits and qualitative traits of all tomato lines (Table 1). The results revealed that newly developed tomato line with orange-yellow coloured fruits have beta carotene of 12.142 mg/kg whereas red coloured varieties/lines exhibited very less beta carotene content (0.204-3.754 mg/kg). Lycopene content of beta carotene rich line was quite lower (7.558 mg/kg) compared to red coloured varieties and lines. Accumulation of beta carotene content in tomato is linked with expression of Beta (B) gene at the expense of lycopene (Stommel 2001). According to Barrett and Anthon (2001) lycopene content of California grown tomato varied from 84.1 to 172.9 mg/kg. Lycopene content among the 52 germplasm lines of tomato at IIHR varied from 25.2 to 328.4 mg/100g dry weight (Shivashankara et al. 2014).

Chlorophyll a and b content also varied significantly among the varieties tested. Chlorophylly a ranged from 0.0448 to 0.0654 mg/100 ml and chlorophyll b ranged from 0.0739 to 0.1136 mg/100 ml. Role of Chlorophyll a and chlorophyll b and their ratio in selective absorption and utilization of light is well proven. Average fruit weight of the newly developed line is 100.52 g which makes it more attractive for table purpose. Fruit yield per plant was also maximum for the newly developed line which may be attributed to its better fruit size. Fruit yield per plant ranged from 1.012 to 2.210 kg/plant among the tested lines. It is evident from this study that DIBER Sel -1 is a beta carotene rich line and this beta carotene rich line will fill the gap of availability of conventionally bred non-GM tomato variety in Indian tomato market and also help in supplementing the requirement of vitamin A to some extent being the '*The Poor's Man Apple*'. This pure line is first successful attempt in release of beta carotene rich tomato cultivar in India and will definitely prove as potential breeding material to the Indian researchers to develop tomato varieties and hybrids with high beta carotene content without genetic manipulation as the trait has been reported to be under monogenic control in *lycopersicum* sp.

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