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INVITED ARTICLE

Indian Durum wheat – its importance and potential as "Health Food"

Durum wheat is the second important wheat species grown in an estimated ten percent area of the total wheat produced in the world. India is one of the largest producers of durum wheat and occupies about 1.5 million-hectare area in dry and hot environment regions of central and peninsular zone comprises of states viz., Karnataka, Maharashtra, Madhya Pradesh, Gujarat, Punjab and Uttar Pradesh (Bundelkhand region) with an estimated production of 8 to 10 percent of the total wheat production. Durum wheat produced from these areas meet international standards and can fetch a better price in national and international market. Best quality durum wheat with excellent appearance, good hectolitre weight, high protein and less yellow berry incidence is predominantly produced in the Malwa plateau of Madhya Pradesh due to longer grain filling period and short vegetative growth in the region. Earlier, its cultivation in India was confined to rainfed areas, but now, with the evolution of semi-dwarf varieties yielding on par with aestivums, its cultivation has spread to irrigated areas. Due to its high yield potential and high tolerance to drought and heat will ensure more production with less irrigation, making wheat cultivation "highly profitable" in Central India.

Due to its distinct resistance to virulences of rusts, *durum* cultivation is essential to minimize the build-up of rusts in Central India, which acts as secondary focus for "Northern Wheat Belt", thereby keeping entire country free from the epidemics of leaf and stem rusts. Durum being highly resistant to Karnal bunt and loose smut, will ensure the availability of produce free from seed borne diseases. A variety of products like spaghetti, macaroni, suji, dalia, vermicelli, noodles, ladoos and other pasta products with consistent cooking quality are made from durum wheat, which has huge demand in national and international market. With the rising demand for speciality foods like pasta in India and other countries. The market for durum

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Dr. Sai Prasad has significantly contributed to the field of Wheat Improvement by developing twenty-two (22) wheat varieties i.e., nine durum and thirteen bread wheat varieties. He played lead role in production of ~23,000q breeder seed of released IARI-wheat varieties, during last 21 years for improving productivity and diversifying wheat cultivation. Resource generated through revolving fund is ~ Rs. 100 crores. He has published ~ 60 research papers in International and National Peer reviewed journals.

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wheat is growing at an exponential rate. Its grain density, combined with high protein content (>12.5%), <10% yellow berry incidence and >7.0 ppm ß-carotene content and gluten strength, make durum, the wheat of choice for producing premium semolina. Low á-amylase activity and high â-carotene content of durums give desirable golden colour to pasta. In North India, it is consumed as noodles, whereas, vermicelli and semolina prepared from durum wheat are preferred in the south.

Credit goes to durum wheat variety HI 8498 (Malvshakti), a truly landmark developed at IARI Regional Station, Indore and notified for release in 1999, for pioneering in bringing durum wheat back in cultivation in central India as this variety outyielded the contemporary bread wheat varieties and showed high levels of resistance to stem and leaf rusts. In fact, durum was the predominant wheat in cultivation in central India until 1950s, but subsequently durum area continually declined and durum wheat went almost out of cultivation due to low yield potential and susceptibility to rust diseases of old durum varieties and landraces. Area under durum wheat considerably increased following the release of HI 8663 (Poshan), another Indore durum variety, in 2008. It combined high yield and strong rust resistance with high and stable yellow pigment content, and hence found favour with farmers and the industry alike. Another unique feature of this variety is its "dual purpose quality" i.e. suitable both for chapatti making and pasta preparations due to its moderate SDS-sedimentation value and high semolina recovery. Mr Yogendra Kaushik, a progressive farmer of Ujjain district in Madhya Pradesh harvested a record production of HI 8663 registering >9.5 tons/ha productivity (Anonymous, 2017). He received the "Best Farmer Award" from the President of India for this achievement. Due to its high and stable yellow pigment content, HI 8663 has remained the first choice of durum wheat based pasta and semolina industry. Area under durum wheat in central India has been steadily increasing following the release of more number of high yielding quality durum varieties in recent years. A brief account of some of the popular varieties is given below.

HI 8498 (Malavshakti)

Developed at IARI-Regional Station, Indore, it is currently the most popular durum variety in central India. Malavshakti is one of the very high yielding wheat genotypes evolved in the history of wheat breeding in India. It's average yield is about 50q/ha. However, due to its responsiveness to higher fertility levels, it is capable of yielding >70 q/ha under good crop management. It out-yielded the contemporary bread wheat varieties breaking the myth that durums are not as good yielders as the bread wheats. It combines high yield with earliness, strong disease resistance and excellent grain quality fit for pasta making and for export. It yields up to 50 q/ha with just 3-4 irrigations, and hence its cultivation can save considerable amount of irrigation water, a limited resource in central India.

MPO 1106 (Sudha)

Developed at JNKVV-ZARS, Powarkheda, it combined high yield with good field resistance to stem and leaf rusts and good grain quality. It is an early maturity (113 days) variety with broad leaves, white & medium dense ears, long awns, amber, lustrous, and bold grains. It has very high protein content (13-14%), 1000 grain weight (40-45 g) and hectoliter weight of 82-83 kg hectoliter. The variety has yield potential of >45 q/ha under good management conditions. It possesses excellent macaroni quality, ideal for pasta products.

MPO 1215

Developed by JNKVV-ZARS, Powarkheda, this durum variety was released in 2010 for irrigated timely sown conditions of Central Zone including the states of Madhya Pradesh, Gujarat, Chhattisgarh, southern Rajastahn and Bundelkhand region of Uttar Pradesh. It is characterized by robust ears, profuse tillering and high number of grains per spike with thousand grain weight ranging between 55-60g. The grains are bold and lustrous with high protein content. It is a very good variety for pasta preparations. The semolina recovery is also high with high yellow pigment content. The yellow berry incidence is very low, free from

Karnal bunt and suitable for export. It is highly resistant to stem and leaf rusts. The demand of this variety is very high and already.

HI 8663 (Poshan)

Developed at IARI-Regional Station, Indore, this durum variety owes its name to its high nutritional value. Being rich in â-carotene, protein and micronutrients, particularly iron and zinc, it can serve as a "naturally bio-fortified health food". Like Malav Kirti, it too has "dual purpose quality" suitable both for pasta preparations and for chapati making. It has high levels of field resistance to stem and leaf rusts including stem rust pathotypes 117-6 and leaf rust pathotype 12-5, the most virulent ones on durum wheat.

HI 8713 (Pusa Mangal)

This is another widely adapted and high yielding Indore-durum variety released in 2013 for irrigated timely sown conditions of Central Zone. It gave an average grain yield of 5.23 t/ha. It showed good levels of field resistance to stem and leaf rusts. It exhibited high degrees of adult-plant resistance to highly virulent pathotypes including 40A of stem rust, and 77-5 and 104-2 of leaf rust. It showed seedling resistance to most pathotypes of leaf rust race 77-group, and of stem rust races 40-group and 117-group. Having rust resistance spectrum different from that of HI 8498 and MPO 1215, it has helped in diversifying the resistance base ensuring protection to timely sown wheat cultivation in central India. It can also serve as a "dual purpose" variety suitable both for making chapati and for pasta preparations due to its moderate SDS-sedimentation value (~30 ml) and high semolina recovery. It can contribute to "nutritional security" in central India, because of its high protein content (~12.0 %), high yellow pigment (~7.16 ppm) and good levels of essential micronutrients like iron, zinc, copper and manganese.

HI 8737 (Pusa Anmol)

In adaptability trials, under timely sown conditions, this Indore-durum variety released in 2015 showed significant yield superiority over the checks MPO 1215 and HI 8498. It is rich in yellow pigment and essential micronutrients like iron and zinc with a high overall acceptability (7.3). It showed high levels of resistance to stem and leaf rusts, and its rust resistance spectrum is different from that of HI 8498 and MPO 1215, popular durum cultivars. It showed good levels of resistance to Karnal bunt also. Hence, it can contribute to diversification of wheat cultivation in central India and enhance the production and productivity of durum wheat in the region.

HI 8759 (Pusa Tejas)

This latest Indore-durum variety gave an average yield of 5.7 t/ha and potential yield of 7.6 t/ha. It showed good levels of field resistance to stem and leaf rusts, the maximum ACI values remaining 6.0 for stem rust and 4.1 for leaf rust. It showed high levels of adult plant resistance to prevalent and virulent pathotypes viz., 40A and 117-6 of stem rust; and 77-5 and 104-2 of leaf rust. Its resistance spectrum is different from currently popular durum cultivars HI 8498 and MPO 1215; and hence can contribute to diversification of stem rust resistance base under wheat cultivation in central India. It is a dual purpose variety suitable for both chapatti and pasta making. It has high protein (12%), yellow pigment (5.7 ppm), iron (42.1 ppm) and zinc (42.8 ppm), less gruel solid loss, and high overall acceptability (7.5). Although released only in 2017, this variety is in great demand among central India farmers.

HI 8777 (Pusa Wheat 8777)

Released by IARI-RS, Indore, it gave 14.2 % superiority over check varieties with a potential yield of 28.8 q/ha under rainfed conditions. Being semi-dwarf and fertilizer-responsive, it is particularly suitable for limited irrigation conditions, yielding up to 35 q/ha with just two irrigations. Its high levels of resistance to stem and leaf rusts can contribute to prevent the early build-up of leaf and stem rusts on October / early November-sown wheat crop. It has good levels of yellow pigment content, high levels of essential micronutrients like Iron (48.7 ppm) and Zinc (43.6 ppm), and with high overall acceptability (7.0).

Nutritional quality: Durum wheat has significantly higher â-carotene content, compared to bread wheat. In addition to â-carotene, several recently released durum cultivars showed superiority in protein, iron, zinc, and copper content as well over popular bread wheat variety Lok 1 (Table 1), and hence, can serve as "bio-fortified health food" toward alleviating malnutrition and ensuring nutritional security, particularly among under-privileged masses. It was found that there was no loss of b-carotene during chapati preparation (Sai Prasad *et al*., 2005).

Table 1. Superiority in nutrient status of some durum cultivars over bread wheat variety Lok-1

Variety	Hectolitre weight (kg)	Protein content (%)	β-carotene (ppm)	Iron content (ppm)	Zinc content (ppm)	Copper content (ppm)
Lok-1 (BW)	80.6	10.6	2.3	35.5	27.2	4.5
HI 8627	82.3	11.0	5.7	49.6	42.1	6.0
HI 8663	83.2	12.3	6.3	47.0	28.8	5.1
HI 8713	82.9	11.7	7.2	35.5	33.6	6.0
HI 8737	83.4	12.1	5.8	38.5	40.0	5.7
HI 8759	83.1	12.5	5.7	42.1	42.8	5.6
HI 8777	82.0	13.3	5.3	48.7	43.6	5.7
MPO 1215	83.0	12.4	5.3	32.0	30.7	5.6

Disease resistance : Durum wheat has better field tolerance to loose smut and Karnal bunt, compared to bread wheat. It was due to outbreaks of Karnal bunt in the 1990s that much of Mexico's domestic wheat production shifted to durum wheat (King, 2006), as mentioned above. In contrast to bread wheat, a greater proportion of durum wheat varieties and germplasm (40%–60%, depending on the origin) showed resistance to races of the Ug99 lineage. This difference was largely attributed to resistance gene *Sr13*, present in high frequency in durum wheat germplasm (Singh *et al*., 2011). In addition, 35 QTLs including nine apparently novel ones were identified for resistance to Ug99 among a panel of 230 tetraploid wheat accessions including 128 durum lines based on a study involving linkage and genome wide association mapping (Laido *et al*., 2015).

Differences in leaf rust resistance between durum and bread wheats have been reported in several studies. Durum wheat, in general, has been showing better resistance to leaf rust in India, compared to bread wheat. A total of 844 durum wheat genotypes and 4429 bread wheat genotypes including advance generation lines and controls (released varieties) under all India coordinated programme were field evaluated at Indore under heavy inoculum pressure for resistance to stem and leaf rusts during 1996-2000. Based on the means from four crop seasons, 73% of durum wheat lines were resistant to leaf rust, compared to 57% of the bread wheat lines (Mishra *et al*., 2002). Only 9% of the durum wheat lines exhibited intermediate to high levels of susceptibility to leaf rust, compared to 25% of the bread wheat lines. In another study conducted at Indore involving seedling tests of 120 genotypes each of durum and bread wheats including released varieties, advance generation lines, indigenous and exotic genetic stocks being utilized in crop improvement programme (Mishra *et al*., 2009), most of the durum lines showed resistance to prevalent and bread wheat-virulent pathotypes of leaf rust race 77-group, and pathotypes of stem rust race 40-group (Table 2). Among the documented genes, *Lr23*, derived from 'Gaza resistance', has commonly been postulated in Indian durum genotypes. However, the leaf rust resistance of most of the Indian durum varieties, particularly to race 77-group pathotypes several of which carry virulence to *Lr23*, is based on `unique' undesignated genes (Bhardwaj, 2013).

Table 2. Seedling resistance of durum wheat and bread wheat genotypes to pathotypes of leaf rust race 77-group and pathotypes of stem rust race 40-group in a glasshouse study conducted at Indore

Leaf rust pathotypes	Percent genotypes showing resistance	
	Durum wheat	Bread wheat
77 (45R31)	98	76
77-1 (109R63)	94	52
77-2 (109R31-1)	96	48
77-3 (125R55)	91	56
77-4 (125R23-1)	95	62
77-5 (121R63-1)	93	22
77-6 (121R55-1)	88	8
77-7 (121R127)	89	43
77-8 (253R31)	95	68
77A (109R31)	98	81
77A-1 (109R23)	93	69
Stem rust pathotypes		
40A (62G29)	78	48
40-1 (62G29-1)	92	57

Thus, durum wheat cultivation in central India is a scientific necessity as the recently released durum varieties are highly resistant to currently prevalent and bread wheat virulent pathotypes of leaf rust race 77-group and stem rust pathotypes 40A and 40-1 (Mishra *et al*., 2009). Hence, durum wheat cultivation in central India can contribute to effective management of both stem and leaf rusts, protecting the entire wheat crop from rust epidemics, since central India serves as the secondary focus of rust infection for the later sown wheat crop in north western plains, the nation's 'wheat bowl'.

Nutritive value and health benefits

In general, yellow pigment content is higher in durum wheat, compared to bread wheat. The yellow pigment imparts yellow hue to the pasta made from durum semolina, and contributes to human health because of antioxidant properties of the constituent carotenoids. Potential beneficial components, including proteins, total phenolics, total flavonoids, carotenoids, tocopherols, and DPPH radical scavenging activity, were investigated in wholemeal of ten bread and ten durum wheat genotypes. In addition, the activity rate of lipoxygenase (LOX) and peroxidase (POD) enzymes implicated in the antioxidant metabolism was determined in a study conducted in Serbia. The results indicated significant differences in proteins and antioxidant compounds between durum and bread wheats. Higher total proteins, wet gluten and antioxidants contents, combined with lower LOX and POD activities, pointed to a higher nutritive value of durum wheat than bread wheat (Zilic *et al*., 2010).

A number of Indian durum varieties are of high nutritive value being rich in protein, yellow pigment, and essential micronutrients like iron and zinc. Recently released (2018) for Central Zone, Indore-durum variety HI 8777 (Pusa Wheat 8777) has high yellow pigment (>6.5 ppm), iron (48.7 ppm) and zinc (43.6 ppm) content. Similarly a JNKVV, Powarkheda-durum variety MPO 1255, released in 2016 for cultivation in the state of Madhya Pradesh, also has high protein (13.8%), yellow pigment (6.51 ppm), iron (50.2 ppm) and zinc (40.0 ppm) content. Durum wheat provides many health benefits, the most important ones of which are described below (Anonymous, 2017a).

A part of balanced diets : Durum wheat is a rich source of many important nutrients. It contains dietary fiber, vitamin B-complex, vitamin E, minerals and zero in fat, saturated and trans fat. It is also low in cholesterol and sodium. Including durum wheat products as a part of diet provides more balanced nutrients intake.

Boosts intake of B-complex vitamins : Durum wheat is rich in B-complex vitamins, especially folate and thiamine. In general, B-complex vitamins are needed for healthy skin, hair, eyes and liver. Thiamine helps to maintain the health of brain and nervous system. Folate supports the regeneration of red blood cell in our body.

Strengthens immune system : Durum wheat is also a good source of essential minerals, such as selenium and iron. Selenium acts as an antioxidant to prevent harmful oxidation damage of cell membranes and DNA. Selenium also strengthens immune system to prevent infection. Iron is beneficial for blood cells regeneration and circulation.

Helps in Weight loss : Products made from durum wheat are digested slowly. This helps one feel full longer and prevents from overeating helping to reduce food intake.

Prevents type 2 diabetes : Durum wheat products make the best choice for people prone to type 2 diabetes because of their low glycemic index.

Improves heart health : Durum contains potassium and is low in sodium. Potassium is important in supporting heart function. It keeps a normal electrolytes balance between cells and body fluid and keeps the heart beating at normal rhythm by lowering blood pressure. Moreover, the selenium content of durum protects heart from infections.

Kidney health : A proper potassium to sodium level is important in keeping our kidneys healthy and in preventing chronic kidney disease.

Healthy bones and nervous system : Durum wheat is a good source of essential minerals. One hundred grams of durum flour contains 17 mg calcium and 47 mg magnesium. Calcium increases the bone density, while Magnesium assures the strength and firmness of the bones. Adequate magnesium is also necessary for nerve conduction and the electrolyte balances of the nervous system. Zinc is a biofactor that plays essential roles in the central nervous system across the lifespan.

Prevents anemia : Iron is essential to produce hemoglobin that carries oxygen to the cells in our body. Eating durum based products prevents iron deficiency and anemia.

Keeps digestive system healthy : Durum semolina is coarse with fiber-rich particles which keep the digestive system healthy.

Innovative approaches followed in India for durum wheat improvement:

- For developing varieties for rainfed / limited irrigation conditions, the breeding populations, particularly F_2 and F_3 generations are being grown and evaluated in the 'target' environment i.e. raising the crop exclusively on conserved moisture / providing only one or two irrigations.
- Rust pathotypes with high degree of virulence on durum wheat like leaf rust pathotypes- 12-5 (29R45), 162-2 (93R39), 12-2 (1R5), 104-2 (21R55), 162-3 (29R7), 11 (0R8) and 106 (0R9); and stem rust pathotypes- 117-6 (37G19), 117A (38G2), 117-1 (166G2), 117-3 (167G3) and 117A-1 (38G18) are being used for screening of breeding populations toward developing varieties with stable and longer lasting rust resistance (Mishra *et al*, 2013).
- Inter-specific hybridization is being carried out involving crosses with bread wheat varieties like HI 1500, HI 1531 and HW 2004 for enhancing tillering in 'shy-tillering' genotypes, and for enriching and diversifying the rust resistance gene pool in durum wheat.
- HI 8498 (Malavshakti), the most popular durum wheat cultivar in central India, has high level of

resistance to most of the stem rust pathotypes including the currently prevalent *40A* and *40-1*. However, it shows susceptibility to few pathotypes of stem rust race *117*-group like *117A*, *117-1* and *117-6*, which are particularly virulent on durum wheat. Hence, effective stem rust resistance genes *Sr2* and *Sr36* of tetraploid wheat origin are being transferred in the background of HI 8498 using marker-assisted selection for incorporating resistance to these pathotypes (Ambati *et al*., 2014, Sai Prasad *et al*., 2014).

- Morpho-physiological traits like 'stay green' nature of flag leaf and canopy temperature are being used for screening the donor lines and the breeding populations toward developing heat and moisture stress tolerant genotypes.
- Varieties with dual purpose quality, good for chapatti as well as pasta making are being developed.
- Lines with high yellow pigment content are being developed using proven donors.

Future thrusts : Development of durum wheat genotypes with

- Suitability for resource conservation technologies and matching production technology without compromising the grain yield – to cut down the cost of wheat production and exhibiting better seed germinability, early seedling vigour, long coleoptiles, more effective tillers and higher root biomass during early as well as later growth stages.
- High micronutrients like iron, zinc and carotene levels – to improve the overall nutritive status of durum wheat to combat the malnutrition in children and women; and for "ensuring food and nutritional security". The accumulation of micro-nutrients in the grains can be improved through the combined use of conventional and molecular breeding approaches.
- Tolerance to early and terminal heat stress to ensure good grain filling with plumpness and lusture.
- Enhanced water use efficiency for increasing the productivity and yield under limited irrigation. Durum genotypes have been developed which showed 100% yield increase compared to rainfed situation, when provided just two irrigations, one at sowing and another at 35 to 45 days after sowing.
- Race non-specific and slow rusting resistance to the three wheat rusts
- Good grain quality for industrial and domestic use by selecting suitable donors for desired quality traits viz., sedimentation value, beta carotene content, hectoliter weight, semolina recovery and cooking quality of pasta products.

Recently, multi-national food companies in India are utilizing Indian durum wheat, which is comparable with its Canadian and Australian counterparts in terms of quality for processing rather than depending on the imports. The pasta industries are looking for more hectoliter weight & hardness to have better extraction rate (~ 68-72%), high protein (~13%), less black tip and dark crease, freedom from yellow berry and Karnal bunt for good finishing of pasta products. Compared to bread wheat, higher heat tolerance of durums ensures higher yields with lesser irrigation. Modern durum varieties are generally resistant to currently prevalent and bread wheat virulent rust pathotypes, and thus, have been contributing to arrest the spread of wheat rusts in the country. Thus, it is an ideal wheat to be grown in Central and Peninsular parts of the country for "ensuring food and nutritional security", increasing employment opportunities through fast food industry and sustainability. Increasing global demand, value addition potential, resistance to diseases, better market price are some of the key factors which make Indian durum wheat an export commodity as well as capable of catering to Indian market. It has an export potential similar to basamati rice. The potential markets for Indian durum can possibly be countries in Middle East, Mediterranean region and Africa after catering the huge demand in Indian markets. An awareness campaign is, therefore, urgently required for the growers, traders and consumers about the importance of durum wheat as high economical crop and for use as "Health Food".

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