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Perspective

PUNJAB AGRICULTURE IN THE POST GREEN REVOLUTION ERA: PERCEPTIONS AND A REALITY CHECK

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The food security situation of newly independent India in the mid 20th century was precarious. Hon'ble Prime Minister Lal Bahadur Shastri appealed to the countrymen in 1965, to miss a meal every Monday evening. Advertisements in newspapers and magazines exhorted readers to eat only two chapatis per meal as every third chapati was made from imported wheat. While seeking prioritization of limited international support, opinion makers classified India in the "can't be saved' category (Paddock and Paddock, 1967). Several pointers from within and outside the country reveal the deep challenge being faced by us then, on the food security front.

Post-independence flush of institution building in the country was responsive to the above predicament. Punjab, for instance, witnessed the establishment of Punjab State Cooperative Supply and Marketing Federation, Punjab State Warehousing Corporation, and Cooperative Agricultural Bank during 1950s, Mandi Board in 1961 and Punjab Agricultural University (PAU) in 1962. This was accompanied by developments such as rural electrification, link road network, market yards and agricultural credit societies. Prior to these developments, Punjab had achieved the unique distinction of consolidation of farmers' land holdings. Arising out of the adversity of partition, land consolidation became the most enabling intervention for *en masse* adoption of tubewell irrigation and farm machinery during the subsequent phase. These components of agricultural development came together in an environment of incentivizing policies, particularly the provision of remunerative support price and assured procurement by the Government agencies (Dhillon and Sohu, 2018; Food Corporation of India came up in 1964 and Agriculture Prices Commission in 1965).

A conducive platform was thus available for the introduction of semi-dwarf wheat varieties from International Maize and Wheat Improvement Center (CIMMYT) in Mexico, which proved to be the pivot of Green Revolution. Nobel laureate Dr Norman E. Borlaug's leadership in developing and then bringing these wheats to India is well known. Teams of scientists working at various centres, including one headed by Dr D.S. Athwal at PAU, Ludhiana saw to technical refinements and other adaptative research requirements (Randhawa, 1973). These included (in case of Punjab) identification and release in 1966 of PV18, first semi-dwarf wheat variety, derived from Mexican wheat germplasm, which outyielded the initial introductions. In another initiative, selection was carried out for uniformity, rust resistance and amber grains in germplasm received from CIMMYT, (followed by large scale seed multiplication in Lahaul-Spiti, during off season), leading to release of revolutionary wheat variety Kalyan in 1967. This material was also identified by Indian Agricultural Research Institute (IARI), New Delhi and G.B. Pant University of Agriculture and Technology, Pant Nagar and was given the common name, Kalyansona. Dr M. S. Swaminathan as Director, IARI, played an important role in engaging with Dr Borlaug and international agencies on one hand and central and state Governments on the other to facilitate the evaluation and adoption of dwarf wheats (Swaminathan, 2017).

The success of semi-dwarf wheats showed the way for similar research at International Rice Research Institute (IRRI) in the Philippines, quickly leading to the advent of semi-dwarf rice varieties, notably IR 8. In Punjab, most of the conditions which had facilitated wheat green revolution, including assured irrigation with electricity powered tubewells, created a ready space for introduction of high yielding semi-dwarf rice. Rice being the main staple food of India, the government policy was understandably inclined towards it. In a scenario of dire food deficit and poorly recognized ecological concerns at that point of time, a major crop transition took place. Punjab became the epicenter of a high impact, dual-crop revolution by early 1970s, in which the government, research and extension agencies and the tireless Punjabi farmers played equally important roles. Along with varieties, the farmers adopted the package of complementary agronomic practices, including that for rice, a non-traditional crop. The result

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was the productivity doubling phenomenon which often goes by the, now much maligned, name of 'Green Revolution'. The sequence of events leading to Green Revolution in Punjab and role of various stakeholders make a fascinating account(Kalkat, 2018).

Punjab's unbroken run as the largest contributor to central food grain pool for about 100 crop seasons, with just 1.53% of the geographic area of the country, is indeed a testimony to the impact of Green Revolution. With this extraordinary performance for over 5 decades, a change of track to sustainable paths, some of which may already be in process carries great urgency. A 'perception impasse' is however making it increasingly hard to assess the ground situation and visualize a consensus future path. Opinion makers, far removed from agricultural reality, are promoting utopian and unfeasible alternatives while completely rejecting the approach which has allowed our large population to become food secure in a substantial measure. Dozens of full length books such as 'The Violence of Green Revolution'(Shiva, 1992) and 'The End of Plenty'(Bourne, 2015) besides innumerable newspaper and magazine articles in this direction, have cast a significant influence on public and policy thinking. There is relatively little recognition of science-based approaches which are now increasingly capable of harmonizing food security needs with environmental and natural resource concerns. This situation is best typified by the manner in which post Green Revolution phase of Punjab agriculture is perceived. Widely held perceptions about Punjab agriculture point to stagnating productivity of major crops, soil health deterioration, fertilizer overuse, indiscriminate pesticide application, toxic residue levels in food commodities and declining farm incomes. Ironically, similar conclusions had been reached by the main author in a 2010 paper(Dhillon *et al*., 2010) on basis of growth rate of wheat and rice productivity in Punjab. A deeper observation and analysis of Punjab agriculture led to proposals for overhauling the methodology employed for such analysis(Kataria and Dhillon, 2020, Sidhu *et al*., 2016) besides emphasizing on use of actual data for soil health and other parameters. The results of analysis performed by service laboratories catering to large number of soil and food commodity samples from all over the state over the decades were compiled for this purpose. The data for other parameters have been drawn from standard sources including the Statistical Abstract of Punjab(*www.esopb.gov.in*). In the sections that follow, the widely held perceptions are examined in light of pertinent data from standard sources.

Perception 1: Stagnation of crop productivity

It is commonly stated that crop productivity has stagnated in the post-Green Revolution phase. Year-to-year variations are expected as agriculture is greatly influenced by weather events, the intensity of which has increased due to climate volatility in recent years. Decadal yield averages can, however, provide a plausible answer to the stagnation issue. These figures for the five major crops (with respect to area) in Punjab, namely wheat, paddy, maize, cotton and sugarcane, are presented in Table 1. The 1981-90 decade serves as a useful post Green Revolution benchmark, wherein benefits from Green Revolution technology components represented by high yielding varieties, irrigation and fertilizers are fully manifested. The average productivity in the decades that follow 1981-90 would thus reflect the post Green Revolution trend and have a bearing on the 'stagnation' issue.

The continued, substantial increase in productivity over 1980s is evident across all crops. Importantly, the productivity in the last decade (2011-12 to 2019-20) continued to post yield gains over previous one in all crops except cotton, e.g., 542 kg/ha in case of wheat, 268 kg/ha in case of paddy (despite greatly increased acreage under lower yielding *Basmati* rice), 717 kg/ha in case of maize and 173 q/ha in sugarcane. Further, the years with highest (record) productivity in all crops fall in the current decade, e.g., 5188 kg/ha of wheat in 2018-19, 6516 kg/ha of paddy (6932 kg/ha of non-*Basmati* rice) in 2017-18, 3981 kg/ha of maize in 2011-12, 827 kg/ha of cotton lint in 2019-20 and 833 q/ha of

Table 1. Average productivity of five major crops in Punjab in last 4 decades

Years	Average productivity				
	Wheat (kg/ha)	Paddy (kg/ha)	Maize (kg/ha)	Cotton (lint) (kg/ha)	Sugarcane (q/ha)
1960-61	1244	1514	1135	270	365
1981-82 to 1990-91	3325	4716	1739	439	614
1991-92 to 2000-01	4124	5030	2163	430	616
2001-02 to 2010-11	4352	5744 (6.8%)*	3028	634	596
2011-12 to 2019-20	4894	6012 (20.2%)*	3745	614 (667)**	769

*Area under *Basmati* rice as a percent of total area under paddy. Exact data on area under *Basmati* rice available only after 2001
** Excluding whitefly epidemic year of 2015-16, when productivity dropped to 197 kg lint/ha

sugarcane in 2017-18. These recent peaks negate the perception of plateauing of yield. It is also during the last decade that foodgrain (wheat + rice) productivity breached the threshold of 12 t/ha. Averaged over 2.5 million ha under non-*Basmati* rice-wheat rotation in the state, this compares well with the best crop production systems in the world. Productivity enhancement has been underpinned by genetic upgradation and matching refinements in production-protection technology package. The clear inference is that technology support matched by farmers' active response have continued to shift the threshold of crop productivity.

The perception of stagnation owes itself to comparing later phases with the largest jump, from a low base, in late 1960s to early 1970s particularly employing compound growth rate, a base-dependent statistic. Despite impressive productivity gains in the region up to the present, it is high time that ecological and environmental consideration, input use efficiency, biotic and abiotic stress tolerance, quality and amenability to value addition take precedence over yield. In any case, imposing arbitrary projections on yield enhancement and labelling the marked increases of previous decades as stagnation, is hardly justifiable.

Perception 2: Deterioration of soil health and over-use of fertilizers

Soil, the dynamic repository of nutrients, determines plant and consequently animal and human health. It is inevitable to relate intensive agricultural practices to depletion of nutrients, though in public discourse, we come across terms such as deteriorated or even dead being employed for soils of Punjab. Changes in soil organic carbon (SOC), a core parameter of soil health can help to assess the apprehensions regarding soil deterioration. A look at the record of 3,82,527 soil samples analyzed from across the state over four decades, however, depicts a continuous improvement in SOC (Fig. 1) from 0.33% in 1981-90 to 0.51% in the last decade. During this period, percentage of samples in the high category (>0.75% organic carbon) has increased from 1.0 to 14.0% and medium (0.4-0.75%) category from 21.0 to 55.0%. These changes are perceived to derive from increase in root biomass of the successively more productive crop varieties grown over the decades as well as an increase in cropping intensity and year-round soil cover on account of a third crop in spring or summer on some acreage.

High use of fertilizers is generally seen as another negative consequence of Green Revolution but we need to recognize that high fertilizer use was driven by our need to produce more food rather than a requirement imposed by the semidwarf varieties of wheat and rice, which could yield similar to tall varieties even under low to medium fertilizer application(Woodward, 1966). The dwarf, non-lodging attributes, however, allow favourable response to high fertilizer application and fertilizer use continued to rise in Punjab for some decades. Highly productive varieties expectedly need better nutrition. But two other equally important factors of higher fertilizer use, which do not get due attention, are increase in cropping intensity from 127% in 1965-66 to 190% in 2019-20 and disruption of natural recycling of nutrients owing to more than 80% of foodgrains (paddy and wheat) moving out of the state. In spite of these factors, a stabilization in fertilizer use has been achieved during the last decade (Fig. 2). While average use of NPK fertilizers in Punjab was 243 kg/ha in 2011-12, it hovered within a narrow range during this decade, closing at 242 kg/ha in 2019-20, in the backdrop of rising crop productivity and cropping intensity during these years.

An adverse soil health impact in post-Green Revolution period pertains to puddling induced changes such as soil compaction and hard pan formation. Further, appearance of micro-nutrient deficiencies, followed by initiation of redressal strategies, as is usual under intensive cultivation have been seen on large areas for zinc and manganese.

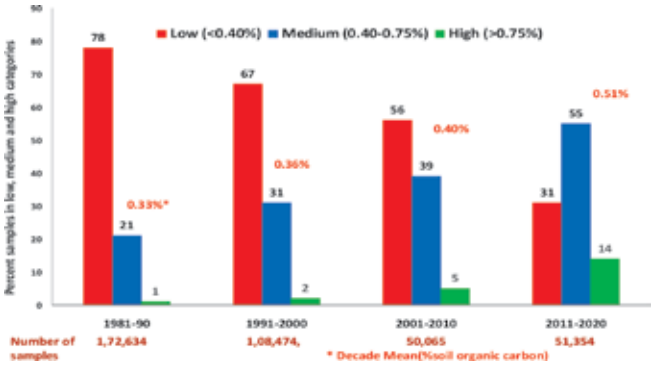

Fig. 1. Soil organic carbon status of Punjab soils

Fig. 2. Fertilizer (NPK) use in Punjab

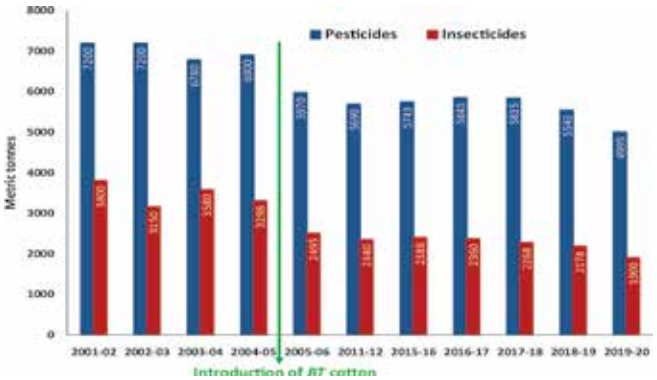

Fig. 3. Pesticide use in Punjab

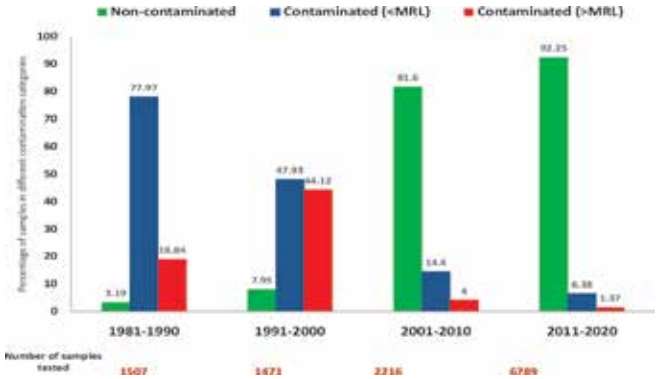

Fig. 4. Pesticide contamination in food samples from Punjab

Perception 3: Indiscriminate use of pesticides

Among pesticides, insecticides are under more intensive focus and their use peaked at 3800 metric tonnes (technical grade) in 2001-02, showing some decline in next 3 years followed by a sharper decline caused by introduction of *Bt* cotton in 2005 (Fig. 3). Insecticide use has shown a further decline since, all the way to 1900 metric tonnes in 2019-20. This is in sharp contrast to the notion of indiscriminate and increasing insecticide use in the state. Over the same period (2001-02 to 2019-20), total pesticide use decreased from 7200 to 4995 metric tonnes. Pesticide use in the last one decade has remained stable with decreasing insecticide use neutralizing the increase in weedicide use.

Apart from the larger picture of pesticide use given above, an integrated pest management (IPM) programme of unprecedented impact has unfolded in Punjab over the last few years. Development and implementation of a comprehensive IPM strategy against cotton sucking pests was taken up on inter-state (Punjab, Haryana and Punjab-adjoining cotton area in Rajasthan) level in 2016 after the devastating cotton whitefly epidemic in 2015 resulted in a crop failure. The gains of this IPM programme are best put in perspective by looking at productivity as well as saving in pesticide costs(Kumar *et al*., 2020). A new record of cotton productivity at 756 kg lint/ha was achieved in the Punjab state during 2016 against the productivity of 197 kg lint/ha during 2015. Additionally, during 2016, the IPM strategy resulted in reducing the pesticide use in the cotton belt by Rs. 2,589/ha (calculated from record of total cotton insecticide sale in cotton growing districts). Continuing the IPM strategy during 2017, 2018, 2019 and 2020 led to productivity levels of 750, 776, 827 and 833 kg lint/ha, the last three being all-time records. Saving in insecticide use during 2017, 2018 and 2019 was to the tune of Rs. 2808/ha, Rs. 3060/ha and Rs. 2532/ha, respectively. It is evident that the pesticide use on cotton and its productivity in the state over the last two decades do not follow the overarching deteriorating trends depicted in a recent study on *Bt* cotton in India(Kranthi and Stone, 2020). A recent perspective on cotton cultivation in Punjab has brought out the role of *Bt* cotton in the state followed by the above discussed major shift to integrated management of sucking pests, particularly whitefly since 2016(Dhillon and Pathak, 2020).

The factors which lead to higher use of pesticides in Punjab include pest build up due to availability of green cover throughout the year and increasing labour cost besides a competitive culture among farmers for higher yield and in our society for faster results. Given these circumstances, some overuse of agro-chemicals including fertilizers, cannot be denied. The data presented above, however, clearly show that the perception of indiscriminate use is unfounded, and the issues are being addressed with good success.

Perception 4: Dangerous levels of pesticide residues are present in food commodities

The carryover of agrochemicals, particularly pesticides as residues in the foodstuffs poses a serious threat to human and animal health. Discerning countries and markets have imposed limits on various agrochemical residues and in recent years these have tended to become progressively stringent. Basmati rice exports from India to European Union, in which Punjab has a significant share illustrates this situation very well. The status of pesticide residues in food commodities in the state has been monitored for several years by the pesticide residue laboratories at PAU - a state of art facility with national accreditation. The food samples analyzed in different decades have been plotted as per residue status of 'not contaminated', 'contaminated at below maximum residue limit (MRL) concentration' and 'contaminated at above MRL concentration' (Fig. 4). The situation during 1980s and particularly 1990s was extremely worrisome. During 1981-90, there were just about 3% of the samples in the not contaminated

Table 2. Wheat and rice productivity (2018-19) in states with high agricultural growth rate and in Punjab

State	Productivity (kg/ha) in 2018-19		Productivity (kg/ha) in Punjab (Year)*	
	Wheat	Rice	Wheat	Rice
Madhya Pradesh	2802	2270	2932 (1981-82)	2287 (1973-74)
Uttar Pradesh	3432	2704	3531 (1985-86)	2910(1977-78)
Bihar	2922	1902	2932 (1981-82)	2007 (1972-73)
Punjab	5188	4132		

Source: Agricultural Statistics at a Glance 2019, Ministry of Agriculture and Farmers' Welfare; Statistical Abstracts of Punjab.
* Year in which Punjab had comparable yield

category and about 19%, having pesticide residue above MRL. The situation worsened in the next decade when 44% samples had residue above MRL, though the number of not contaminated samples increased to about 8%. The situation has completely reversed in the last decade (2011-20), when only 8% sampled were contaminated and almost 92% were in the not contaminated category. More importantly, just 1.37% samples have residues above MRL. The country average for the decade stands at 2.4% samples above MRL(Department of Agriculture & Farmers' Welfare, 2018). The overall progress has been rather dramatic and brings the ideal of even complete residue free status within reach. Restricting to targeted and judicious use of safe pesticides within the ambit of IPM and awareness generation on residue related issues have been the key to this major success.

Perception 5: Crop productivity in the Punjab state lags behind other states and farmers' income in the state is declining

Comparisons of agricultural situations across large regions or states can be instructive, but indices like growth rate often do not make good sense in light of variable natural endowments, distinct agro-ecologies and economies. The analysis is further vitiated by the widely varying starting points with respect to productivity level as we move from one region to the other. Agricultural growth in high productivity states like Punjab and Haryana, often gets categorized as sluggish or negative compared to other states which are now catching up and passing through a productivity phase similar to the 1970s and 1980s in high productivity states for crops like wheat and rice (Table 2).These data reflect the incongruence of such comparisons involving Punjab, and unwittingly give an advantage to some states with low starting point which shows up as fast growth.

Declining farm household incomes in Punjab is another often raised issue. As per NSSO as well as NABARD surveys, the average monthly income of agricultural households in Punjab continues to be the highest in the country with a wide margin over the second best Haryana which has a similar agro-ecology, and is about two and a half times the national average (Table 3).

CONCERNS

A fact-based reorientation of the perceptions reveals the ground situation and helps us to focus our efforts on real concerns and issues. An alarming concern (more pressing than the domain of perceptions dealt with above) is the depletion of groundwater and the state needs to shift sizeable area from paddy, to other less water requiring crops with comparable remunerations. Further, paddy straw management is a burning issue, where a large number of technological and policy interventions are now being implemented(Mahal *et al*., 2019). Replenishment of soil nutrients is another important concern. Even if Punjab is able to manage water resources and diversify the cropping system, the mining of soil nutrients will continue as long as agricultural produce is moved out of state and recycling of nutrients is disrupted. The state will have to deal with replenishment of soil nutrients. A further concern is the widening gap between the income from agriculture and other sectors. The percentage share of state agriculture (crops and livestock) in GSDP has reduced from 60.2

Table 3. Average monthly income of agricultural households in Punjab

State	Average monthly income of agricultural households (Rs/household/year)		
	NSSO (2013)	NABARD (2016)	NSSO (2019)
Punjab	18059	23133	26701
Haryana	14434	18496	22841
India	6426	8931	10218

to 23.5 during 1975-76 to 2015-16. During the same period, though, the workforce engaged in agriculture has decreased, but to a much lesser extent (from 62.7 to 35.6). This asymmetry is indicative of disguised underemployment and lowered returns in agriculture as compared to the other sectors.

There has been some progress in water management through the development and popularization of short duration varieties of paddy having less water requirement. High yielding, short duration *Parmal* rice varieties (such as PR 121 and PR 126), which are 3-5 week earlier in maturity than long duration varieties, have covered about 70% of the non-basmati acreage of the state in the last three years and are estimated to save 10-15% irrigation water(Mangat and Dhillon, 2018). A similar water saving is approximated from the use of laser land levelers which now have a state wide coverage(Sidhu *et al*., 2007). In absence of enactment and implementation of 2008-09/2014/2018 state legislations to regulate the date of transplanting, the serious water table decline would have been much worse. Direct seeded rice (DSR) has emerged as a water and labour saving option(Bhullar *et al*., 2018). DSR was adopted on 20% of the rice growing areas in the state, largely in response to COVID pandemic induced labour shortage during 2020.

Promoting natural resource conservation technologies which apparently may carry no immediate economic gain, but are demanding in terms of changes in mindset as well as practices, represents a daunting task, even when long term benefits such as higher productivity and nutrient use efficiency due to improved soil health are evident. The issue therefore is of suitably filling up the 'incentive vacuum' with measures ranging from awareness driven increase in consumer preference for food produced sustainably to direct government support to the farmers adopting these practices.

Crop diversification, particularly replacement of rice on a substantial acreage remains an urgent requirement for sustainability. Gradual but continuous increase in area under vegetables and fruits from 239 thousand to nearly 380 thousand ha during last decade, (2009-10 to 2019-20), has resulted from increasing demand, development and popularization of improved varieties and cultivation practices and provision of better seed and planting material(Punjab State Department of Horticulture, *www.punjabhorticulture.com/AYP_Crops*) but gluts and price crashes are being faced because marketing and processing infrastructure and export opportunities are tending to lag behind.

Building equitable value chains would be the key to crop diversification where knowledge partnership and produce aggregation could provide farmers with the vital balance of power in the market ecosystem. Quality originating on the farm and passed on with assurance of a traceability system can make growers, traders and processors better aligned for mutual benefits. Back flow of benefits to the farmer should be ensured which would in turn take care of long term viability of the chain.

It is thus time to move on from the unfounded perceptions to addressing real concerns in Punjab agriculture and promote knowledge partnership with farmers in a quest for natural resource sustainability and high quality produce, leading to overall improvement in livelihood and social indices.

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