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Short Communication

Deciphering yield formation process in wheat under contrasting tillage conditions

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Abstract

Non-availability of the genotypes bred under conservation agriculture practices and presence of large interaction for genotype x management, points to the fact that the gain can be further consolidated through cultivation of specifically adapted genotypes under conservation agriculture (CA) in India. Differentially adapted 42 genotypes were grown for two consecutive years under three tillage conditions. During favorable year (2011-12) for crop growth, conservation agriculture (CA) provided the opportunity for benefits of traits like seed width, seed length, embryo width, initial vigour indicated by normalized difference vegetation index (NDVI), shoot biomass and days to maturity to be accumulated into higher biomass at harvest and higher grain yield realization due to improved harvest index (HI). Simultaneously, under conventional tillage raised bed condition probably due to poor water retention, traits relevant for moisture stress condition like NDVI 1 representing initial vigour and more ground coverage in vegetative stage, peduncle length, last node length, biomass, HI showed positive correlation with yield. Changing association between traits under different management condition warrants for caution in the selection criterion Path analysis shows that selection for higher biomass with better HI and higher yield under CA can lay foundation for realization of better gain for yield in future.

Key words: Conservation agriculture, correlation coefficient, path coefficient, wheat, yield

Increasing pressure on natural resources to meet future food requirement is perhaps biggest concern of the researchers as well as policy planners. The target seems to be more challenging in view of unsustainable agriculture practices followed globally and changing environment. New generation crops or genotypes which are in tune to healthy agriculture practices are likely to play an important role. Conservation agriculture practices revolving around no tillage, residue retention and crop rotation are likely to make impact on yield and crop performance, under low input as well as high input environment. Conventional crop production agronomy comprising tilling of top soil and removing or incorporating or burning the residue have serious soil degradation and environmental issue [1]. CA as a healthy agriculture practices, has been proposed to address these issues.

Physical, chemical and biological changes induced by CA practices are perhaps large enough to introduce genotype x environment interaction (G x E). Of the many traits, responsible for such interaction, root traits are perceived to be the most critical. Role of plant traits for adaptation under CA have remained largely unexplored since from the beginning and therefore, if explored can provide much needed stimulus for the next big jump in yield [2-4].Improved understanding of rooting pattern and their correlation with other productive traits will help in breeding new cultivars adapted to CA practices. Modern-day genotypes which are adapted to high-input, intensive agricultural systems [5] had been bred without considering these traits.

Annual gain of 1.1 % in wheat yield in Australia has been realized through improved management, improved genotype and genotype x management interaction [6]. He found genotype x management interaction as the biggest source of variation and therefore is foremost for further improvement in yield realization. Kharub *et al*. [7], reported significant differences in root density among tillage systems and

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genotypes were observed in the early stages of crop growth but not at more advanced growth stage. A decrease in root density was also reported under zero-tillage condition in maize [8]. Various root traits which have been reported important for breeding point of view include rooting depth, root distribution, angle of seminal roots, increased root elongation and reduced root gravitropism. Beside these traits, emergence from depth and establishment under uneven terrain and heavy residue load under conservation agriculture condition like kernel weight, embryo size, coleoptile length, thickness, initial vigour, seedling biomass were also reported to be important [9, 10]. This study was carried out to quantify genotype x management interaction and to identify traits responsible for specific adaptation under different management.

Field experiments were conducted during the year 2011-12 and 2012-13 at IARI Research Farm to dissect the trait of importance for different tillage systems. The plot size was 4 rows of 4 meter length on two beds with furrow-furrow spacing of 70 cm and resulting into effective area of 5.60 m^2 for each plot under CA and CTRB of planting. Under CA, whole residue of the previous crop was retained in the furrow. Under CTRB fresh beds were made with bed maker after 4-5 tillage operations with disc harrow and rotary tillers. Under CTFB, six rows of 4 meter length spaced at 23 cm each were seeded with *Winterstiger* seeding machine after 4-5 tillage operation with disc harrow and rotary tillers. The seed rate was 100 kg/ha for CTFB and 80 kg/ha for CTRB and CA. Recommended package and practices were followed to raise a good crop of wheat.The plant material comprised of 39 genotypes of wheat bred under the programme on breeding wheat for CA at IARI, New Delhi for adaptability to different management practices along with three standard checks *viz*., DBW17, HD 2967 and PBW 550 are recently released varieties for normal sown irrigated condition of north-western plain zone of India (Table 1).

ANOVA and correlations were generated for each trait through SAS 9.3 software. Significance of G x E interaction was judged through F test against error degree of freedom. Path analysis was done for yield in each environment by Indo Stat version 8.5. Analysis of variance identified that environment and all environmental interactions were highly significant ($p < 0.0001$) for majority of the traits under study (table not shown). The main effect of genotypes was significant ($p < 0.0001$) for all traits under study. Environment, which in the present case is management i.e. CA, CTFB, CTRB, was found to be the biggest source of variation for all the traits [11].

Yield was found to be significantly and positively correlated with seed length, width, shoot biomass, NDVI2, spike length, tillers per meter row length, height, internode length, biomass, harvest index, thousand test weight and days to maturity (Table 1). Yield was negatively correlated with canopy temperature. However, under CTRB seed width, main root length, root biomass, number of spikelets, and biomass were positively correlated with yield. Under CTFB condition NDVI, biomass, harvest index, no of grains and thousand seed weight were positively correlated with the yield. The positive correlation with seed width, seed length and shoot biomass under permanent bed condition is in the tune of previous reports which shows that vigour is important trait for selection of adaptability under zero till condition and all these traits lead to high initial vigour [12].

Other important traits for higher yield realization under CA can be high tiller per meter length because CA provide comparatively longer optimum environment for tillering as well as spike length. Positive correlation with height under CA was largely due to less lodging in taller genotypes and increased spacing between the furrow and better anchoring. Biomass was very significantly correlated with yield in all three environments and therefore, can be the most important selection criterion for increasing yield for all kind of environments. Absence of correlation of HI with yield in CTRB points out the fact that high water and heat stress toward terminal stage under freshly made bed condition with no residue, genotypes with lower biomass face more stress due to poor ground coverage. Another important trait, which was showing positive correlation with grain yield but only CA condition was days to maturity.It was largely because, zero till and residue retention increased the duration of maturity by three to five days in both short duration as well as in long duration varieties providing more opportunity for better translocation of assimilate towards grain development.

It is clear from the figures for different production environment that contribution of direct and indirect effect from independent variable toward yield are fairly large in all environment except CTRB in 2011-12 and therefore, it can be inferred that the traits selected for the construction of the path diagram are enough to explain the yield variability. During favorable year for crop production i.e., 2011-12, biomass and harvest

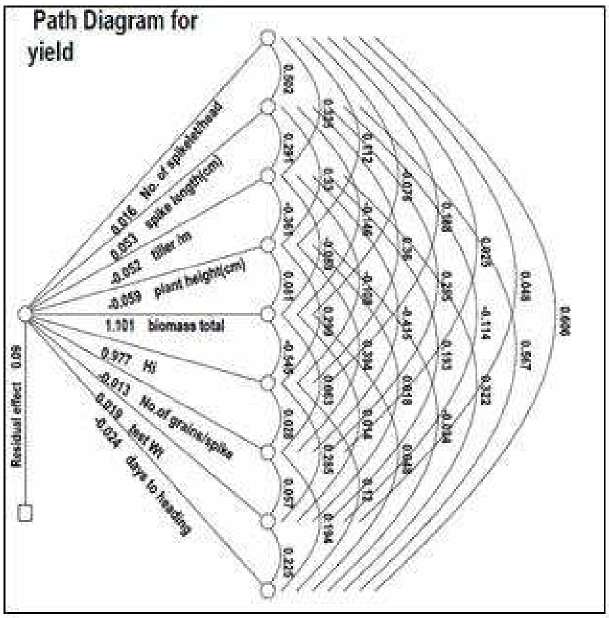
Table 2. Correlation of yield with other traits under study

Traits	2011-12			2012-13		
	CA	CTRB	CTFB	CA	CTRB	CTFB
Seed length	0.206*	-0.149	0.119	-0.005	-0.082	-0.08
Seed width	0.208*	0.231*	-0.135	0.049	-0.047	0.039
Embryo length	-0.085	0.13	-0.124	-0.01	-0.067	-0.144
Embryo width	0.147	0.106	-0.123	0.264**	0.096	-0.121
Coleoptile length	-0.067	0.145	0.04	-0.206*	-0.190*	-0.105
Main root length	0.037	-0.226*	-0.174	0.069	0.051	0.164
Mesocotyl length	0.021	0.136	-0.01	-0.17	-0.137	-0.007
Culm length	-0.003	-0.14	0.016	0.075	0.054	0.166
Shoot biomass	0.331**	-0.106	0.148	-0.028	0.11	-0.019
Root biomass	0.122	0.223*	-0.17	-0.133	-0.052	-0.084
Canopy Temp	-0.229*	-0.144	-0.114	-0.1	0.015	0.011
No. of spikelets	0.053	0.193*	-0.101	0.044	-0.104	0.156
Spike length	0.182*	-0.346**	-0.03	0.05	-0.014	0.022
Tillers/m	-0.186*	-0.156	0.129	0.133	0.16	-0.029
Plant height	0.318**	-0.099	0.13	0.388**	0.074	0.107
Peduncle length	-0.07	-0.144	0.139	0.13	0.228*	-0.195*
LNTSL	0.296**	-0.337**	0.094	0.079	0.277**	-0.154
Biomass total	0.781**	0.851**	0.811**	0.822**	0.570**	0.654**
HI	0.320**	0.015	0.245*	0.682**	0.616**	0.551**
No. of grains	0.164	-0.049	-0.209*	0.078	-0.01	-0.005
Test weight	0.326**	-0.141	0.256**	0.046	0.027	0.167
Days to heading	0.168	-0.172	0.032	0.008	0.054	0.114
NDVI1	.230*	-0.051	0.241*	-0.146	0.387**	-0.172
NDVI2	NA*	NA	NA	-0.107	0.048	0.016
NDVI3	NA	NA	NA	-0.049	-0.043	0.175
NDVI4	NA	NA	NA	0.107	0.152	0.064
Days to maturity	NA	NA	NA	0.196*	0.135	0.068

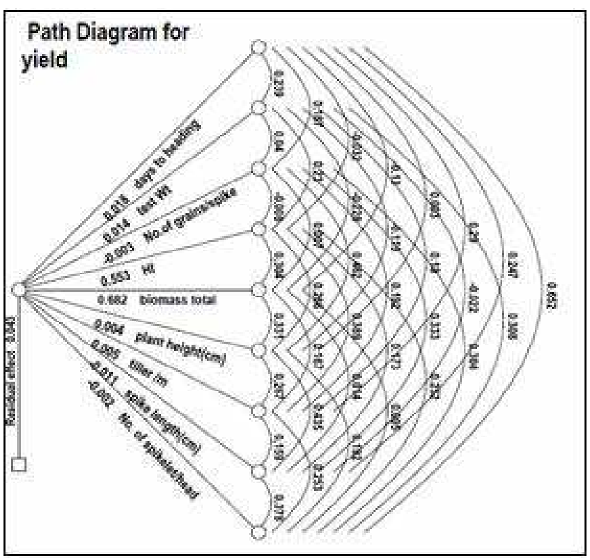
NA: Not available; CTFB = Conventionally tilled flat bed; CTRB = Conventionally tilled (freshly prepared) raised bed with no residue

index have near perfect direct effect on yield in CA and CTRB environment i.e. every unit increase in these variables lead to a almost unit increase in yield. However, under CTFB condition, biomass though, have near unit direct effect on yield but for harvest index, direct effect was 0.514, largely because, translocation of accumulated photosynthate toward sink was hampered in the genotypes with weak stem and lodging. However, during stressed year, direct effects of biomass and HI on yield become comparatively smaller. Under CA, largely unexplored traits like seed width, seed length, embryo width, shoot biomass contributed toward initial vigour indicated by NDVI. Slightly taller genotypes could accumulate more total biomass at harvest and non lodging under CA ensured high harvest index (HI) during the year favourable for plant growth. In the second year (2012-13), under conventional tillage and raised bed condition, abiotic stress exposure to the crop was so acute that the parameters relevant for adaptation to moisture and heat stress environment like NDVI 1 representing initial vigour and more ground coverage, peduncle length, last node length and biomass were highly expressed and become instrumental for yield differences. Changing association between traits under different management condition warrants for caution in the selection criterion.

It is quite, surprising that none of the component traits (tillers no., no. of grains and thousand seed weight) contributed directly toward increased yield, under any of the environment. However, higher yield realization under CA condition came through positive association between seed weight and HI. Zhou *et al*. [13] in their study on genetic gain analysis also found out no change in any of component traits except thousand seed weight in region. The present study, therefore clearly indicates that increase in yield in future can come through increased biomass and HI. Foules *et al*. [14] has also reported to increasing instances of improving yield in winter wheat through higher biomass rather than better partitioning. Many authors [15] still believe, wheat is still sink limiting and to overcome this limitation, photoperiod sensitivity can be exploited to increase number of fertile florets. In our material, no variation was found for photoperiod genes and therefore, no of grains showed hardly any effect either directly or indirectly in any of the environment. Wheat production, though increasing globally over the years steadily, but requires quantum jump to meet the future challenges of food and nutritional security. Through correlation analysis we can only identifies the mutual associations among the parameters whereas path analysis gives relative magnitude of each effect. Path analysis clearly shows that only CA provide scope for establishing genetic differences among genotypes under stressed and non stressed years through traits like biomass and HI. Our study clearly shows to make yield gain more sharp; biomass and HI can be simultaneously improved through higher seed weight realization under CA.



(a)



(b)

Fig. 1a-c: Direct and indirect effect of important traits influencing wheat grain yield under, a) CA during 2011-12; b) CA during 2012-13

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