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Correlation And Path Coefficient Analysis for Combining High Grain Yield and Protein Content Based on Nitrogen Remobilization Efficiency in Wheat (*Triticum aestivum* L.)

Tilak Raj[1], Sukhpreet Kaur Sidhu[2], Ashutosh Srivastava[2*] and S. S. Sidhu[3]
[1]Krsihi Vigyan Kendra (FDK), [2]Department of Botany, [3]Department of Math. Stat. and Physics, Punjab Agricultural University, Ludhiana-141004
*Corresponding Author E-mail: aksri_du@yahoo.com
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ABSTRACT

Three wheat cultivars namely PBW-550, PBW-502 and PBW-343 sowed under two nitrogen levels (120 and 180 kg N ha^{-1}). The grain yield was highly positively correlated with biological yield (r = 0.9766) followed by total plant nitrogen at maturity (r = 0.9688), remobilized nitrogen at post anthesis (r = 0.9296), number of kernel per spike (r = 0.9195), grain protein yield (r = 0.9069), number of spikes per plant (r = 0.8236) and remobilized efficiency (r = 0.8068). Path analysis of grain yield showed that the vegetative nitrogen at maturity stage had significant positive direct effect ($P_{9\ 11}$ = 0.5329) on grain yield. Vegetative nitrogen at maturity had significant positive correlation with remobilized nitrogen ($r_{9\ 3}$ =0.6764) and it contribute more indirectly through grain protein yield ($r_{9\ 2}\ P_{2\ 11}$ = 0.0267). Number of kernel per spike had direct effect on grain yield ($P_{6\ 11}$ = 0.0205) while the indirect effect through remobilization efficiency was more ($r_{6\ 10}\ P_{6\ 11}$ = 0.1793). Pearson analysis showed that a significant high and positive correlation of grain yield with harvest index (r = 0.9833) followed by vegetative nitrogen at milky stage (r = 0.9693). The result of this study indicate that the nitrogen and partitioning are independently inherited routes for accumulating nitrogen in the grain and thus can be combined to produce cultivars with either of routes alone, similarly, the accumulation and remobilization of dry matters are complimentary routes for increasing grain yield and when combined improved nitrogen accumulation.

Key words: *Wheat, NUE, Correlation, Path analysis and Grain protein concentration*

INTRODUCTION

Wheat (*Triticum aestivum*) used as a staple food providing more protein than any other cereal crop. Grain yield and grain protein concentration are important traits affecting the economic value of wheat. Grain protein is of primary importance in determining the bread-making quality of wheat. Improvement in grain protein quality is therefore, a major objective in bread wheat breeding programs world-wide[2].

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Achieving this goal without concurrent loss in grain yield has been difficult due to well documented negative association between these two economically important traits[5]. concluded that a genetic increase in the amount of grain nitrogen could be accomplished by increasing nitrogen utilization efficiency through (i) increasing the nitrogen uptake efficiency of the crop or (ii) increasing the nitrogen remobilization efficiency of the crop. Whole plant studies of nitrogen uptake, remobilization and partitioning have been extensively used as integrative measures of the complex physiological processes involved in nitrogen utilization efficiency; however, the relationships among these different physiological strategies for enhancing grain nitrogen have been contradictory. The extra nitrogen supplied in the nitrogen 120 treatment generated significant increases in above ground dry matter amount at both anthesis and at the end of the growing cycle. The above ground dry matter nitrogen content was also greater at anthesis[15]. At anthesis dry matter accumulation reached a maximum with 140 Kg N ha^{-1} applied at planting, while nitrogen accumulation increased with each added increment of per plant nitrogen[6]. About 20% of the above ground nitrogen at anthesis is located in the ear[14]. Plants well supplied with nitrogen have higher photosynthetic activity. In addition to[8], found a high significant correlation (0.97) between chlorophyll concentration and nitrogen content in the wheat leaves. Furthermore these plant usually have slow leaf senescence after anthesis, optimizing grain filling and NUE[18,9]. Higher nitrogen rates mainly increased dry matter production and leaf area index in growing season and at reproductive growth stage[10]. Grain yield, nitrogen accumulation and remobilization in wheat may be modified by fertilization timing, tillage system, and environmental conditions. Nitrogen accumulation was generally greater at ear emergence than at anthesis net N accumulation in fertilized plant ceased by ear emergence. Consequently further growth during grain filling depended on remobilization of nitrogen accumulated in the vegetative plant parts[12]. The major source of nitrogen partitioned to the grain is the remobilization of nitrogen resulting from organ senescence whereas the major source of dry matter partitioned to the grain is current photosynthesis[7].

Although significant variation exists for nitrogen uptake in wheat, it has not been consistently associated with high grain protein concentration. The duration of nitrogen uptake is positively associated with grain protein concentration but it was more critical for grain protein yield than for grain protein concentration. Improved translocation efficiency is the basis of high protein in some currently released wheat cultivars. However, several other studies found no relationship between grain protein concentration and translocation efficiency. Nitrogen harvest index has been used by many researchers as a measure of partitioning efficiency in an attempt to link grain protein concentration with grain yield. The nitrogen harvest index (NHI) stands out among the NUE components, because it indicates the translocation rate of nitrogen from the straw to the grain; normally it tends to vary from 69% to 98% [3,16]. a great NHI value indicates high value of grain protein concentration (GPC)[4,19]. this relationship is supported by[11] who reported that the nitrogen uptake rate and the concentration of nitrogen in grains are effective criteria for the selection of wheat with high NUE. These inconsistencies in the relationships of nitrogen uptake, translocation and partitioning with grain protein concentration point to the different physiological routes in plants to accumulate grain nitrogen. The earlier studies lacked germplasm expressing high levels of grain yield and grain protein concentration simultaneously. A recently released cultivar PBW-550, suggests that genetic improvement in grain yield and grain protein concentration can occur simultaneously. This cultivar may provide the opportunity to study traits related to nitrogen accumulation, remobilization and partitioning in varieties too in expressing high grain yield and high grain protein concentration simultaneously. Thus there is need Selection criteria for combining high grain yield and protein content based on nitrogen remobilization efficiency in wheat.

MATERIAL AND METHODS

The experiment was carried out at the experimental area and laboratories of the Punjab Agricultural University, Ludhiana during *rabi* season 2010-11.The bread wheat cultivars used in this experiment were PBW-550, PBW-502 and PBW-343. The experimental design was a split plot with three replications. Nitrogen was applied at a rate of 120 and 180 kg N ha^{-1}. Plant samples were taken at anthesis, anthesis + 4 days, anthesis + 8 days, anthesis + 12 days, Milk stage of kernel development, Soft dough stage of kernel development, and Physiological maturity. Anthesis was scored when anthers in the central florets of 50% of the spikes in a plot had dehisced, and maturity when almost all the spikes in plot showed complete loss of green color.

Plant samples were dried to constant moisture (4-5%), weight and separated in a vegetative component (leaves and stems) and a grain component. The vegetative components were weight and ground through 2-mm screen. Vegetative and grain nitrogen concentration were determined by standard Micro-Kjeldhal technique[1]. A conversion factor of 5.7 was used to convert grain nitrogen concentration to grain protein concentration[17]. The various parameters referring to dry matter and nitrogen remobilization *viz.*, grain protein concentration, grain protein yield at maturity, remobilized nitrogen at post anthesis, biological yield, number of spikes per plant, number of kernels per spike, 1000-kernels weight, total plant nitrogen at maturity, vegetative nitrogen at maturity, remobilization efficiency at post anthesis, and grain yield were recorded and calculated as follow. Pearson correlation coefficient and path analysis were analyzed by using statistical software SPSS 7.5.

a) *Measured at anthesis*

a) $$TDM\ (g\ m^{-2}) = Weight\ of\ above\ ground\ dry\ matter$$

b) $$TPN\ (g\ m^{-2}) = TDM\ X\ TPN\%$$

(TDM) Total dry matter (g m^{-2}) and (TPN) Total plant N (g m^{-2})

b) *Measured Post Anthesis*

a) $$MXVN\ (g\ m^{-2}) = \frac{Weight\ of\ vegetative\ dry\ matter\ X\ Tissue\ N\ percentage}{100}$$

b) $$ACCN\ (g\ m^{-2}) = TPN_m - TPN_A$$

c) $$ACCDM = TDM_m - TDM_A$$

d) $$RN = MXVGN - VGN_m$$

e) $$RE\ (\%) = \frac{RN}{MXVGN}\ X\ 100$$

(MXVN) Maximum vegetative N (g m^{-2}), (ACCN) Accumulated N (g m^{-2}), (ACCDM) Accumulated dry matter, (RN) Remobilized N and (RE%) Remobilization Efficiency (%)

c) *Measured at maturity*

a) $$BY = weight\ of\ above\ ground\ dry\ matter\ at\ harvesting$$

b) $$GPC\ (\%) = N_{Concentration\ in\ grain}\ X\ 5.7$$

c) $$GPY = GY\ X\ GPC(\%)$$

d) $$TDM = Weight\ of\ above\ ground\ dry\ matter\ (At\ Constant\ mositure)$$

e) $$TPN = TDM\ X\ \frac{TPN\ percentage}{100}$$

f) $$HI = \frac{GY}{TDM}$$

g) $NHI = \frac{TGN}{TPN}$

h) $VGN = TVGDM\ X\ \frac{VGN\ percentage}{100}$

(BY) Biological yield, (GPC) Grain protein concentration (%), (GPY) Grain protein yield, (TDM) Total dry matter, (TPN) Total plant N, (HI) Harvest index, (NHI) Nitrogen harvest index and (VGN) Vegetative N.

RESULTS AND DISCUSSION

In the present investigations, various physiological and biochemical changes related with nitrogen partitioning efficiency in wheat grown under different nitrogen levels were studied at different development stage. Physio-biochemical traits showed various responses with increasing of nitrogen level among different varieties. The grain yield was highly positively correlated with biological yield (r = 0.9766) followed by total plant nitrogen at maturity (r = 0.9688), remobilized nitrogen at post anthesis (r = 0.9296), number of kernels per spike (r = 0.9195), grain protein yield (r = 0.9069), number of spikes per plant (r = 0.8973), grain protein concentration (r = 0.8236), remobilization efficiency (r = 0.8068), while vegetative nitrogen at maturity (r = 0.4517) had no correlation with grain yield (Table 1).

The correlation of remobilization efficiency was high with grain protein concentration (r = 0.9183) followed by grain protein yield (r = 0.9093), number of kernels per spike (r = 0.8652), total plant nitrogen at maturity (r = 0.8232), number of spikes per plant (r = 0.7574), biological yield (r = 0.7111). Vegetative nitrogen at maturity showed no correlation with remobilization efficiency. Number of kernels highly correlated with grain protein yield (r = 0.9092). 1000-grain weight had no correlation while biological yield showed maximum correlation (r = 0.9490) with total plant nitrogen at maturity followed by grain protein yield (r = 0.9358). Correlation between number of kernels per spike and grain protein yield was maximum (r = 0.9092). Path coefficient analysis divides the correlation coefficient analysis into direct and indirect effects. It allows, then the separation of direct influence of each yield components themselves. For that purpose, a cause effect system was formed (Fig.1).

Path analysis of grain yield showed that the vegetative nitrogen at maturity stage had significant positive direct effect ($P_{9\ 11}$ = 0.5329) on grain yield (Fig 1). Vegetative nitrogen at maturity had significant positive correlation with remobilized nitrogen ($r_{9\ 3}$ = 0.6764) and it contribute more indirectly through grain protein yield ($r_{9\ 2}\ P_{2\ 11}$ = 0.0267). The direct effect of grain protein yield found to be low ($P_{2\ 11}$ = 0.0350) while its correlation in correlation analysis was due to its indirect effect through remobilization efficiency ($r_{2\ 10}\ P_{2\ 11}$ = 0.1884).

Remobilized nitrogen had negative direct effect on grain yield ($P_{3\ 11}$ = -0.2516). However, its lower value of correlation in correlation analysis due to its indirect contribution through vegetative nitrogen at maturity ($r_{3\ 9}\ P_{3\ 11}$ = 0.3605). The direct effect of biological yield was negative but in correlation coefficient it shows the positive correlation. Number of spikes per plant contribute directly ($P_{5\ 11}$ = 0.0029), its direct effect on grain yield in the correlation analysis was masked by the indirect effect through vegetative nitrogen at maturity ($r_{5\ 9}\ P_{5\ 11}$ = 0.2478). Number of kernels per spike had direct effect on grain yield ($P_{6\ 11}$ = 0.0205) while the indirect effect through remobilization efficiency was more ($r_{6\ 10}\ P_{6\ 11}$ = 0.1793). Remobilization efficiency contribute more directly ($P_{10\ 11}$ = 0.2072) than indirectly ($r_{10\ 5}\ P_{10\ 11}$ = 0.0023) through number of spikes per plant.

From this path analysis it can be concluded that grain protein yield, remobilized nitrogen, biological yield, number of spikes per plant, number of kernels per spike, vegetative nitrogen at maturity and remobilization efficiency contribute towards yield. Vegetative nitrogen at maturity had significant direct effect on grain yield (Table 2). The following traits were used for correlation between grain yield and traits at different stages in wheat:

1. Total Plant Dry Matter at anthesis stage (TDMA)
2. Total Plant Nitrogen at anthesis stage (TPNA)
3. Vegetative Nitrogen at Anthesis + 4days stage (VG4D)
4. Vegetative Nitrogen at Anthesis + 8 days Stage (VG8D)
5. Vegetative Nitrogen at Anthesis + 12 days Stage (VG12D)
6. Vegetative Nitrogen at Milky Stage (VGM)
7. Vegetative Nitrogen at Soft Dough Stage (VGS)
8. Maximum Vegetative Nitrogen at post anthesis stage (MXN)
9. Harvest index at physiological maturity stage (HI)
10. Nitrogen harvest index at physiological maturity stage (NHI)
11. Sum of harvest index and nitrogen harvest index (SUM)
12. Total Plant Dry Matter at physiological maturity stage (TDMM)
13. Accumulated Nitrogen at post anthesis stage (ACCN)
14. Accumulated Dry Matter at post anthesis stage (ACCDM)
15. Grain yield at physiological maturity stage (GY)

In order to quantitatively analyze the relationship among physiological traits and grain yield, Pearson analysis was applied (Table 3). A significant high and positive correlation of grain yield with harvest index (r = 0.9833) followed by vegetative nitrogen at milky stage (r = 0.9693). Grain yield had no correlation with total dry matter at anthesis. Correlation between accumulated dry matter with total dry matter at maturity was significantly positive (r = 0.8543). Accumulated nitrogen at anthesis was negatively correlated with total dry matter at anthesis (r = -0.0236). Nitrogen harvest index, sum of harvest index and nitrogen harvest index, total dry matter at maturity negatively correlated with total dry matter at anthesis. Correlation of maximum vegetative nitrogen significant positive with vegetative nitrogen at eight days after anthesis (r = 0.9986). Vegetative nitrogen at anthesis + 4 days positively correlated with total plant nitrogen at anthesis (r = 0.8270). Nitrogen harvest index and negative correlation with maximum vegetative nitrogen at past anthesis stage (r = -0.3951). Sum of harvest index and nitrogen harvest index had no correlation with vegetative nitrogen four days after anthesis. Correlation were especially strong for total dry matter at maturity and grain yield, accumulated dry matter and total dry matter at maturity, total dry matter at maturity and vegetative nitrogen twelve days after anthesis. Harvest index and total dry matter at maturity more significant positive correlation with grain yield[13].

The results of this study indicate that nitrogen and partitioning are independently inherited routes for accumulating nitrogen in the grain and thus can be combined to produce cultivars with either route alone. Similarly, the accumulation and remobilization of dry matter are complementary routes for increasing grain yield and when combined with improved nitrogen accumulation and redistribution, should result in cultivars with high grain yield and grain protein concentration .In order to bring together these complementary routes, breeders must select for these traits in addition to grain yield and grain protein concentration alone. It is concluded that grain protein concentration could be improved by enhancing grain nitrogen. Similarly, grain yield could be increased by selecting for harvest index. Grain protein concentration improved without reducing grain yield by selecting cultivars with both high grain protein yield and remobilization efficiency.

Table 1: Pearson correlation analysis between grain yield and different traits in wheat

Characters	1	2	3	4	5	6	7	8	9	10	11
1. Grain protein concentration	1.000										
2. Grain protein yield	0.9847**										
3. Remobilized N	0.6511**	0.7622**									
4. Biological yield	0.7741**	0.8703**	0.9298**								
5. No. of spikes per plant	0.7079**	0.7859**	0.8600**	0.8646**							
6. No. of kernels per spike	0.8668**	0.9092**	0.8121**	0.8589**	0.8449**						
7. 1000-kernel weight	0.5024*	0.3802	-0.2054	-0.0209	0.0144	0.3009					
8. Total nitrogen at maturity	0.8720**	0.9358**	0.9306**	0.9490**	0.8621**	0.9202**	0.0953				
9. Vegetative nitrogen at maturity	0.0818	0.0755	0.6764**	0.4974*	0.4649	0.2656	-0.7189	0.4112			
10. Remobilization efficiency	0.9183**	0.9093**	0.6727**	0.7111**	0.7574**	0.8652**	0.5250*	0.8232**	0.0272		
11. Grain yield	0.8236**	0.9067**	0.9296**	0.9766**	0.8973**	0.9195**	0.0925	0.9688**	0.4517	0.8068**	1.000

** Significant at 5% level

* Significant at 1% level

Table 2: Path coefficient analysis of grain yield with different traits

Characters	1	2	3	4	5	6	7	8	9	10
1. Grain protein concentration	**-0.0207**	0.0345	-0.1638	-0.1146	0.0021	0.0177	0.0336	-0.4767	-0.0435	0.01903
2. Grain protein yield	-0.0204	**0.0350**	-0.1918	-0.1289	0.0023	0.0186	0.0254	-0.5116	0.0402	0.1884
3. Remobilized N	-0.01351	0.0267	**-0.2516**	-0.1377	0.0025	0.0166	-0.0137	-0.5088	0.3605	0.1394
4. Biological yield	-0.0161	0.0305	-0.2339	**-0.1481**	0.0026	0.0176	-0.0014	-0.05189	0.26510	0.1473
5. No. of spikes per plant	-0.0147	0.0275	-0.2164	-0.1280	**0.0029**	0.0173	0.0008	-0.4713	0.2478	0.1569
6. No. of kernels per spike	-0.0179	0.0319	-0.2044	-0.1272	0.0025	**0.0205**	0.0201	-0.5031	0.1416	0.1793
7. 1000-kernel weight	-0.0104	0.0133	0.0517	0.0031	0.0003	0.0062	**0.0670**	-0.0521	-0.3813	0.1088
8. Total nitrogen at maturity	-0.0181	0.0328	-0.2341	-0.1406	0.0026	0.0188	0.0064	**-0.5467**	0.2193	0.1706
9. Vegetative nitrogen at maturity	0.1698	0.2647	-0.1702	-0.0737	0.0013	0.0055	-0.0481	-0.2248	**0.5329**	0.0056
10. Remobilization efficiency	-0.0191	0.0319	-0.1693	-0.1053	0.0023	0.0178	0.0318	-0.4501	-0.0145	**0.2072**

(Bold values shows direct effect)

Table 3: Correlation analysis between grain yield and traits at different growth stages (Data pooled for wheat cultivars and nitrogen levels)

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. TDMA	1.000														
2. TPNA	0.1853														
3. VG4D	0.5014*	0.8270**													
4. VG8D	0.5528*	0.8027**	0.9921**												
5. VG12D	0.2661	0.9414**	0.9298**	0.9204**											
6. VGM	0.3595	0.9475**	0.9530**	0.9394**	0.9833**										
7. VGS	0.3253	0.9506**	0.9404**	0.9262**	0.9920**	0.9941**									
8. MXN	0.5171*	0.8281**	0.9930**	0.9986**	0.9390**	0.9534**	0.9424**								
9. HI	0.1283	0.8128**	0.8198**	0.8127**	0.9343**	0.8766**	0.9074**	0.8351**							
10. NHI	-0.8575	0.0152	-0.3985	-0.4389	-0.723	-0.1910	-0.1217	-0.3951	0.1155						
11. SUM	-0.8122	0.1402	-0.2602	-0.3005	0.0740**	-0.0501	0.0219	-0.2546	0.2664	0.9882**					
12. TDMM	-0.0029	0.8530**	0.7766**	0.7579**	0.9318**	0.8697**	0.9007**	0.7871**	0.9774**	0.2289	0.3729				
13. ACCN	-0.0236	0.6337**	0.6969**	0.7010**	0.8097**	0.7127**	0.7449**	0.7220**	0.9184**	0.1809	0.3172	0.9107**			
14. ACCDM	-0.4374	0.6435**	0.4566	0.4240	0.6846**	0.5793*	0.6304**	0.4624	0.7740**	0.5626*	0.6653**	0.8543**	0.8008**		
15. GY	0.1991	0.8897**	0.8527**	0.8472**	0.9693**	0.9311**	0.9538**	0.8701**	0.9833**	0.0625	0.2124	0.9710**	0.8596**	0.7313**	1.000

** Significant at 5% level,

* Significant at 1% level

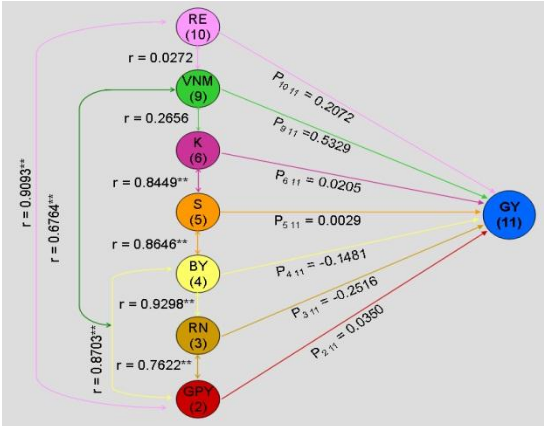

Fig. 1: Path coefficient of the direct effects of grain protein yield (GPY), remobilized nitrogen (RN), biological yield (BY), number of spikes per plant (S), number of kernels per spike (K), vegetative nitrogen at maturity (VNM) and remobilization efficiency (RE) on grain yield.
(The single headed arrows indicate path correlation coefficient.
The double headed arrows indicate simple correlation coefficient.
**** Significant values).**

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