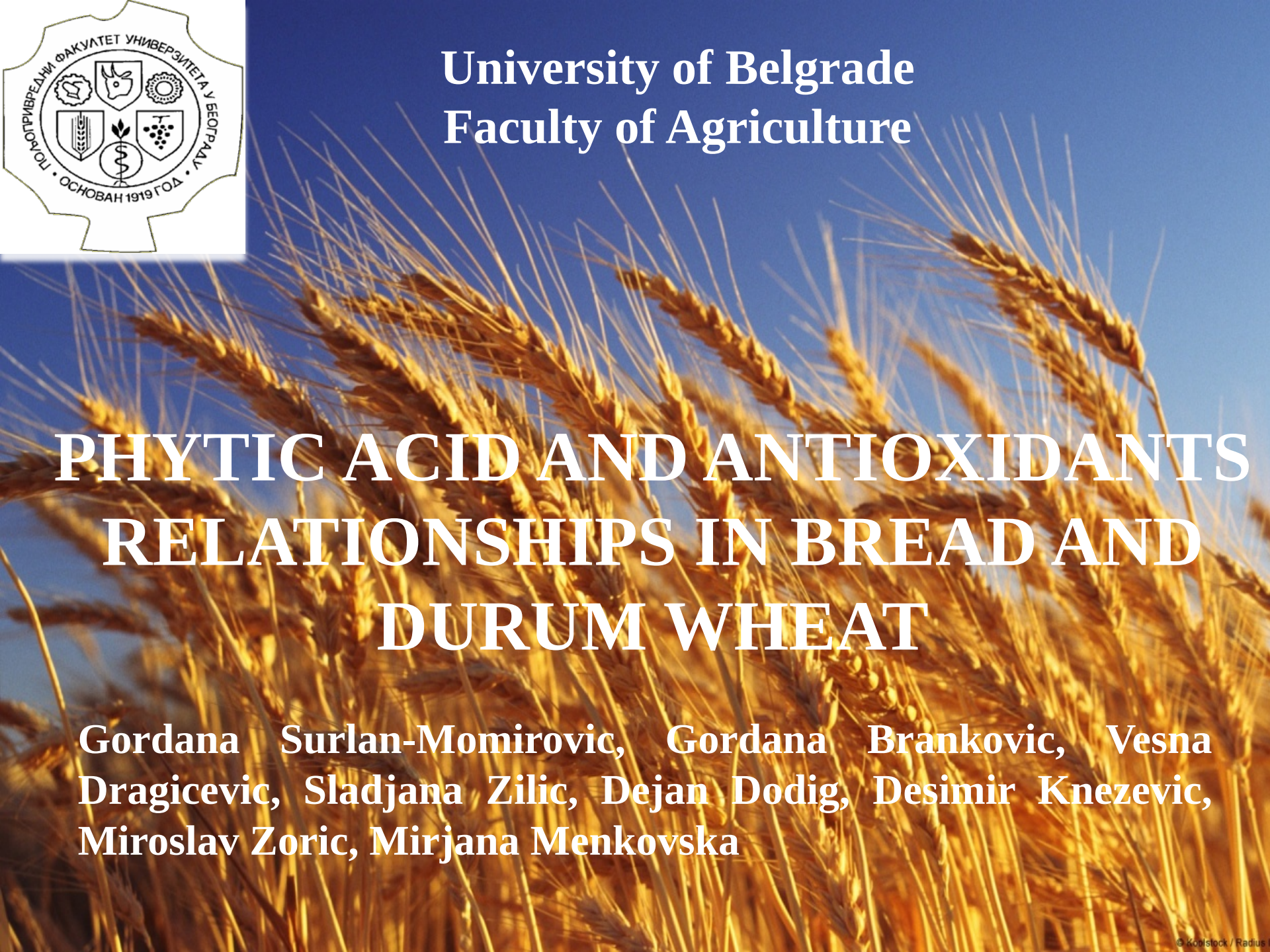


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PHYTIC ACID AND ANTIOXIDANTS RELATIONSHIPS IN BREAD AND DURUM WHEAT

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INTRODUCTION

❑ **Wheat** has traditionally been selected for its yield and functionality, for example, baking or biscuit values, while the nutritional value of the grain and its improvement has been almost neglected. However, during the last 10 years much more attention has been paid to the phytonutrients of wheat as potential antioxidants acting on the health benefits.

❑ Nutritional values of wheat vary according to their nutrient content and digestibility. Variation of nutrient content is under genetic and environmental control. Wheat grains are mainly composed of carbohydrates (65–75% starch and fibre) and proteins (7–12%), but also contain lipids (2–6%), water (12–14%) and micronutrients (Pomeranz, 1988).

❑ **Phytic acid** (*myo*-inositol (1,2,3,4,5,6)-hexa*kis*phosphate or $InsP_6$) represents storage form of phosphorus (P) in seeds. It typically represents 50-85% of seed total phosphorus, and can be from one to several percent of seed dry weight. (Khan et al., 2007; Raboy, 2001). A substantial fraction of all phosphorus taken up by crop plants from soil is translocated ultimately to the seed and synthesized into $InsP_6$. Therefore, this compound represents a major pool in the flux of phosphorus through agricultural ecology. It was estimated recently that the amount of phosphorus synthesized into seed $InsP_6$ by crops each year represents a sum equivalent to >50% of all fertilizer phosphorus used annually world-wide.

❑ Most seed $InsP_6$ is deposited as mixed phytin salts of mineral cations such as potassium, magnesium, calcium, iron, zinc, copper, manganese. Seed phytins are deposited primarily in storage microvacuoles or protein bodies as discrete inclusions referred to as globoids. During germination, phytins are broken down by endogenous phytase enzymes, releasing their P, *myo*-inositol and mineral contents for use by the growing seedling (Svečnjak et al., 2007; Raboy 2001).

❑ Nutrition rich in phytic acid can substantially decrease micronutrients apsorption as calcium, zink, iron, manganese, copper due to salt excretion by human and non-ruminant animals as poultry, swine and fish. They have in common the lack of the ability to digest and utilize phytic acid. It can lead to micronutrients deficiencies, anemia, tissues hypoxia, heart failure, insufficient imuno-competency, poor attention spans, impaired fine motor skills and less memory capacity, hypogonadism and dwarfism in men, growth retardation in infants and children, orificial and acral dermatitis, diarrhea, alopecia, impaired reproductive performance and difficulties in parturition, especially for populations in developing countries and poor people with inadequate nutrition (Reicwald and Hatzack, 2008; Lönnerdal, 2002, Walter et al., 1997).

❑ The recent studies also indicated an important potential benefit of phytate to lower cancer rate, increase seedling vigor, and decrease aflatoxin development in grain (Ortiz-Monasterio et al., 2007).

❑ In the context of poultry and swine production, because the bulk of grain P is phytic acid P and is excreted, to provide for an animal's nutritional requirement for P and optimal productivity, feeds must be supplemented either with an available form of P or with the enzyme phytase. Phytic acid-derived P in animal waste can contribute to water pollution, a significant problem in the United States, Europe and elsewhere.

❑ **β-carotene** has the role as the secondary pigment in photosynthesis, and also phoprotective as it prevents chlorophyl from degredation (Cunnigham and Gantt, 1998). Also, it reacts with the nascent oxygen and superoksid anions, as photosynthesis by-products and exhibit the antioxidant power. β-carotene represents the precursor of the vitamin A. Vitamin A deficiency (VAD) causes night-blindness, xerophthalmia, keratomalacia, bone growth deficiencies, and weakens the immune system. The clinical effect of VAD is inversely related to the age of patient, and the mortality of children with severe VAD can reach 50% (Yonekura-Sakakibara and Saito, 2006).

❑ **Phenols**, secondary metabolites in plants, have an antioxidant, antimutagenic, antimicrobial and anti-inflammatory role (Zilic et al., 2009). Phenolic compound have protective role against degenerative diseases-heart disease and cancer in which reactive oxygen species (ROS) are involved-superoxide anion O2·-, hydroxyl HO· and peroxy ROO· radicals, and mixed nitrogen–oxygen species (RNS)-nitric oxide (NO•) and peroxynitrite (ONOO–) (Dykes and Rooney, 2007).

❑ **Thiols** are the organic compounds that contain a sulphydryl group. Among all the antioxidants that are available in the body, thiols constitute the major portion of the total body antioxidants and they play a significant role in defense against reactive oxygen species. Total thiols are composed of both intracellular and extracellular thiols either in the free form as oxidized or reduced glutathione, or thiols bound to proteins. Among the thiols that are bound to proteins, albumin makes the major portion of the protein bound thiols, which binds to sufhydryl group (PSH) at its cysteine-34 portion. Apart from their role in defense against free radicals, thiols share significant role in detoxification, signal transduction, apoptosis and various other functions at molecular level (Prakash et al., 2009). Decreased levels of thiols has been noted in various medical disorders including chronic renal failure and other disorders related to kidney, cardiovascular disorders, stroke and other neurological disorders, diabetes mellitus, alcoholic cirrhosis and various other disorders. Therapy using thiols has been under investigation for certain disorders.








❑ **Wheat** is the most widely grown crop and traditionally has been selected for its technological functionality resulting in the selection of bread (*Triticum aestivum* L.) and durum (*Triticum durum* Desf.) wheat varieties.

❑ The flour made from the bread wheat exhibits all the characteristics and properties required for making bread. The preeminence of bread wheat in baking industry is mainly due to the presence of a unique viscoelastic gluten protein complex that makes it the best cereal grain suitable for the manufacture of leavened bread. Fractions of gluten, glutenins and gliadins, are significantly associated with bread-making quality (Shewry et al., 1992; Zhu and Khan, 2004).

❑ **Durum wheat** is not ideal for use in the bread making industry due to its gluten characteristics. The large quantities of yellow pigment, high vitreousness, test weight, and proteins, especially favorable gluten composition of good strength, are the durum cultivar qualities of primary interest to the food industry. The international grading of the durum wheat varieties is determined based on degree of grain vitreousness and hardness (Dexter et al., 1988; Dowel et al., 2000). Semolina used for end use products should have a small and equal particle size for a good hydrating quality. Most durum products belong to the Mediterranean kitchen. They can be divided in paste products, like noodles or couscous, and non paste products, like bread or bulgur (Dick & Matsuo, 1988) or semi finished products like semolina. It depends on the region if mainly pasta or other durum products are consumed and produced.

AIM OF INVESTIGATION

The objectives of this study were to use multivariate genotype by trait (GT) analysis to:

- ❑ unravel the relationship between phytic acid, antioxidants, other measured chemical-technological traits and agronomic traits in bread and durum wheat as breeding objectives;
- ❑ identify positively or negatively correlated traits, indicate the possibility of indirect selection for the trait of interest;
- ❑ visualize genotype traits profiles (strengths and weaknesses of a genotype), which is important for the proper selection of parents and comparison of selection strategies.

MATERIALS AND METHODS

❑ Genetic material used in this research consisted of 15 bread wheat genotypes (*Triticum aestivum L. ssp. vulgare*) and of 15 durum wheat genotypes (*Triticum durum* Desf.). This genetic material was selected from the Gen Bank of Institute of Field and Vegetable Crops in Novi Sad and from Maize Research Institute “Zemun Polje”.



❑ The trials were sown at the three locations: Rimski Sancevi (RS) fields owned by Institute of Field and Vegetable Crops in Novi Sad, Zemun Polje (ZP) fields owned by Maize Research Institute “Zemun Polje” in Zemun Polje and Padinska Skela (PS) fields owned by Institute PKB “Agroekonomik” in Padinska Skela during 2010-2011 and 2011-2012.



❑ The experiments were designed as randomized complete block design (RCBD) in four replicates. Plot consisted of five rows 1 meter long with inter-row spacing of 0.2 meter. Elementary plot consisted of three rows of 0.6 m^2 area. Due to danger of bird attacks in Zemun Polje, protective net was used few weeks before harvesting.



Table 1. Names (codes), origin, type and pedigree of bread wheat (*Triticum aestivum* L. ssp. *vulgare*) genotypes

Code	Genotype	Origin	Type	Pedigree
P1	Žitarka	Croatia	winter*	OSK-6-30-20/SLAVONKA/3/EPHRAT-M-68/OSK-154-19//KAVKAZ
P2	Stephens	USA	winter*	NORD-DESPREZ//(CI-13438)PULLMAN-101
P3	Renan	France	winter*	MIRONOVSKAYA-808/MARIS-HUNTSMAN//VPM-1/MOISSON/3/COURTOT; MIRONOVSKAYA-808/MARIS-HUNTSMAN/3/VPM-1/MOISSON//COURTOT; MIRONOVSKAYA-808/MARIS-HUNTSMAN/3/VPM-1/MOISSON//9*COURTOT
P4	Caldwell	USA	winter*	PD-5724-B-3-5-P-8-2*2//SIETE-CERROS-66
P5	Abe	USA	winter*	ARTHUR*4/3/PD-6028-A-2-15-9-2//RILEY*2/RILEY-67
P6	Auburn	USA	winter*	SIETE-CERROS-66/ARTHUR//PD-6850/6/AFGHANISTAN(S)/PD-5374/4/KNOX*2//FRONTANA/EXCHANGE/3/(SIB)RILEY/5/ARTHUR*5//ARTHUR(SIB)/AGATHA/3/PD-6729
P7	Frankenmuth	USA	winter*	NORIN-10/BREVOR(SELECTION-14)//YORKWIN/3/2*GENESEE(A-3141)/4/(A-5115)GENESEE*3/REDCOAT
P8	Apache	France	winter*	AXIAL//NRPB-84-4233
P9	ZP AU 12	Macedonia	winter**	(L40*PROTEINKA)//OROVCANKA
P10	Marija	Croatia	winter *	ZG-4527-68/KAVKAZ//ZG-1971-70
P11	87/Ip homozigot	Serbia	winter **	L-99//POBEDA
P12	Tecumseh	USA	winter*	MINHARDI/WABASH/5/FULTZ(S)/HUNGARIAN//W-38/3/WABASH/4/FAIRFIELD/6/REDCOAT(SIB)/(CI-12633)WISCONSIN-245/7/PD-427-A-1-1-3*3/KENYA-FARMER
P13	Pobeda	Serbia	winter*	SREMICA//BALKAN
P14	Zemunska rosa	Serbia	winter*	SKOPLJANKA//PROTEINKA
P15	Ludwig	Austria	winter*	ARES//FARMER

* -cultivar; ** -line, USA-United States of America

Table 2. Names (codes), origin, type and pedigree of durum wheat (*Triticum durum* Desf.) genotypes

Code	Genotype	Origin	Type	Pedigree
D1	37EDUYT No. 7922	CIMMYT	facultative**	ALTAR84/STINT//SILVER_45/3/POHO_1/4/GREEN_14//YAV_10/AUK
D2	37EDUYT No. 7896	CIMMYT	facultative**	AINZEN_1/3/SRN_3/AJAIA_15//DON87/4/MINIMUS/COMB DUCK_2//CHAM_3
D3	37EDUYT No. 7817	CIMMYT	facultative**	SNITAN/3/STOT//ALTAR84/ALD
D4	Varano	Italy	winter*	CAPEITI-8/CRESO//CRESO/3/VALFORTE(VALF)/TRINAKRIA
D5	37EDUYT No. 7821	CIMMYT	facultative**	AINZEN-1//PLATA_6/GREEN_17
D6	37EDUYT No. 7880	CIMMYT	facultative**	ALTAR 84/STINT//SILVER_45/3/LLARETA INIA/4/
D7	10/I	Serbia	winter**	WINDUR//RODUR
D8	SOD 55	Slovakia	winter*	KORALL ODESSKIJ//GK PANNONDUR
D9	37EDUYT /07 No. 7803	CIMMYT	facultative**	RASCON_37/2*TARRO_2/4/ROK/FGO//STIL/3/BISU_1/5/MALMUK_1/SERRATOR_1
D10	DSP-MD-01 No. 66	ICARDA	facultative**	848.10.6/OTB2//GDR1
D11	34/I	Serbia	winter**	SOD 55//KORIFLA
D12	37EDUYT No.7820	CIMMYT	facultative**	AINZEN-1/3/MINIMUS_6/PLATA_16//IMMER
D13	37EDUYT /07 No. 7857	CIMMYT	facultative**	CBC 514 CHILE/SOMAT_4/3/HUI/YAV79//DON87
D14	37EDUYT /07 No. 7849	CIMMYT	facultative**	CBC 505 CHILE/LLARETA INIA/3/D86135/ACO89//PORRON_4
D15	120/I	Serbia	winter**	WINDUR//KAVADARKA

CIMMYT-The International Maize and Wheat Improvement Center (Mexico); ICARDA-International Center for Agricultural Research in the Dry Areas (Syria); *-cultivar; **-line

❑ **Chernozem** is the type of the soil at the Rimski Sancevi and Zemun Polje location and also humogley at the Padinska Skela location. Chemical characteristics of soil were determined by using standard methods of agrochemical analysis (Dzamic et al., 1996) on dried and fragmented samples.

❑ The following **agronomic traits** were measured: **grain yield, thousand grain weight, plant height, spike length, number of grains per spike, grain length, grain width, grain thickness, coefficient of the productive tillering.**

❑ Measured **chemical-technological traits** and methods of analyses were: **phytic acid** (Latta and Eskin (1980) modified by Dragicevic et al. (2011)); **inorganic phosphorus** (Pi) (Pollman (1991), modified by Dragicevic et al. (2011)); **β-carotene** (AACC-American Association of Cereal Chemists (1995) 14-50); **total phenols** (Simic et al. (2004)); **free protein sulfhydryl groups (PSH)** (de Kok et al. (1981)) and **grain vitreousness** (Kaludjerski and Filipovic (1998) for durum wheat genotypes only). For these analyses flour was produced (particles size <500 micrometer) by grinding in Laboratory Mill 120 Perten (Perten, Sweden). For the contents analyses of: phytic acid, total phenols, PSH, β-carotene, and Pi apsorbances were measured with the Shimadzu UV-1601 spectrophotometer (Shimadzu Corporation, Japan).

❑ **Genotype by trait (GT) biplot** represents typical multivariate analysis of standardized matrix of genotyp × trait, and was constructed according to model of Yan and Rajcan (2002).

❑ A genotype by trait biplot can help understand the relationships among traits (breeding objectives) and can help identify traits that are positively or negatively associated, traits that are redundantly measured, and traits that can be used in indirect selection for another trait (Yan and Tinker, 2006).

❑ GT biplot helps to visualize the trait profiles (strength and weakness) of genotypes, which is important for parent as well as variety selection (Yan and Kang 2003).

❑ GT analysis was done within R 2.9.0 program environment (R Development Core Team, 2010).

RESULTS AND DISCUSSION

- If two trait vectors enclose an acute angle, their correlation is positive, if enclosing an obtuse angle, the correlation between them is negative, and if the angle is right, the traits are independent. The performance of the genotype of a particular trait is better if the angle between the genotype vector and trait vector is less than 90°, close to the average if it is 90°, and worse if it is more than 90°.

- Length of the genotypic vector represents the distance from the origin and the genotype marker and measures the distance of the genotype from the "average" genotype., ie. its contribution to the G or GE effect, or both (Yan and Tinker, 2006). Genotypes with a shorter vectors have a small contribution to the G and/or GE, genotypes with longer vectors have a larger contribution to the G and/or GE. Therefore, genotypes with the longest vectors are either the best or the worst or most unstable for certain traits.

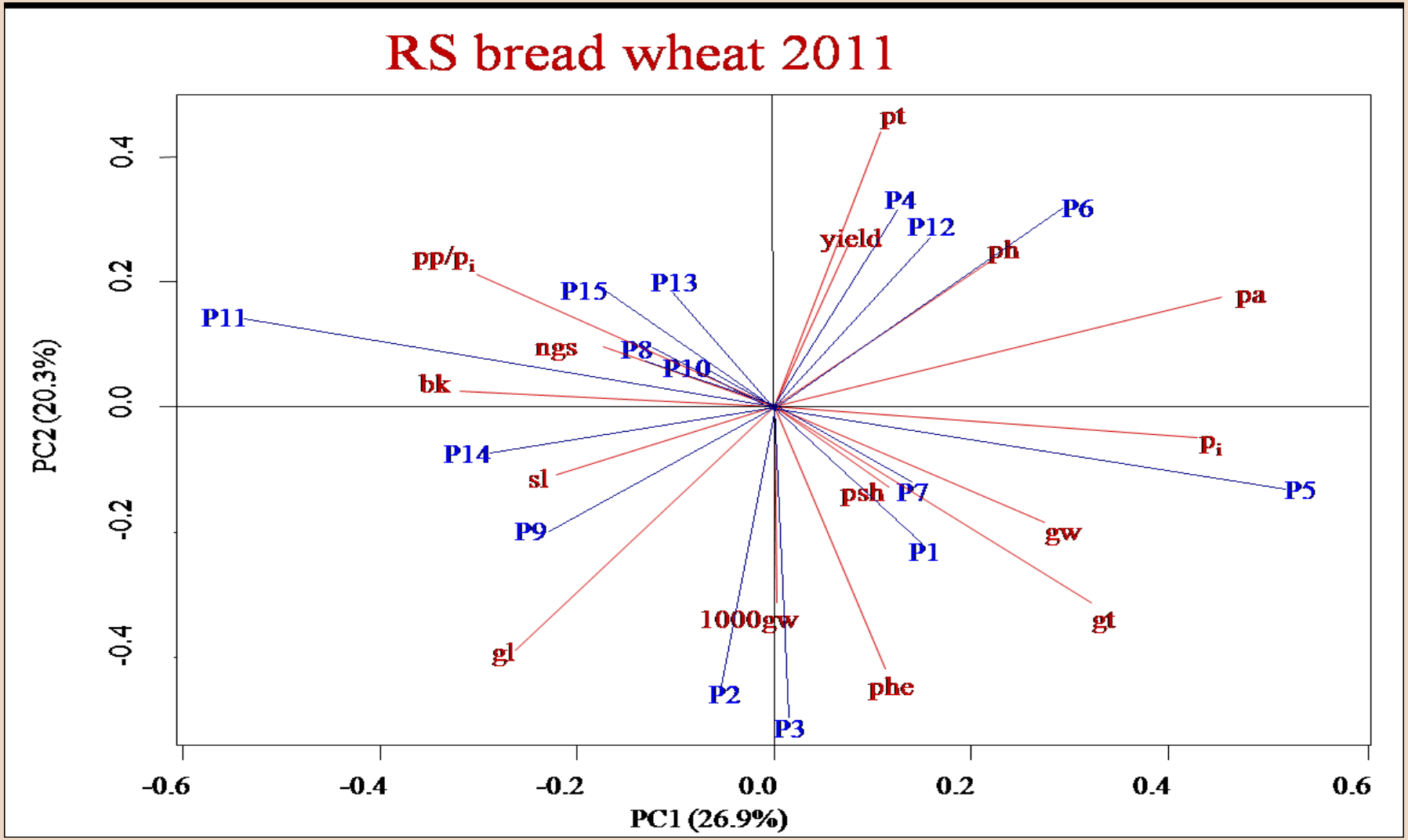


Figure 1. A genotype by trait (GT) biplot representing 15 bread wheat genotypes (P1-P15) measured for 9 agronomic and 6 chemical-technological traits for Rimski Sancevi location in 2011. (yield; 1000gw-thousand grain weight; ngs-number of grains per spike; ph-plant height; pt-productive tillering; sl-spike length; gt-grain thickness; gl-grain length; gw-grain width; phe-total phenols; bk-β-carotene; pa-phytic acid; p_i-inorganic phosphorus; pp/p_i-phytic acid phosphorus and inorganic phosphorus relation; psh-protein free sulfhydril groups.

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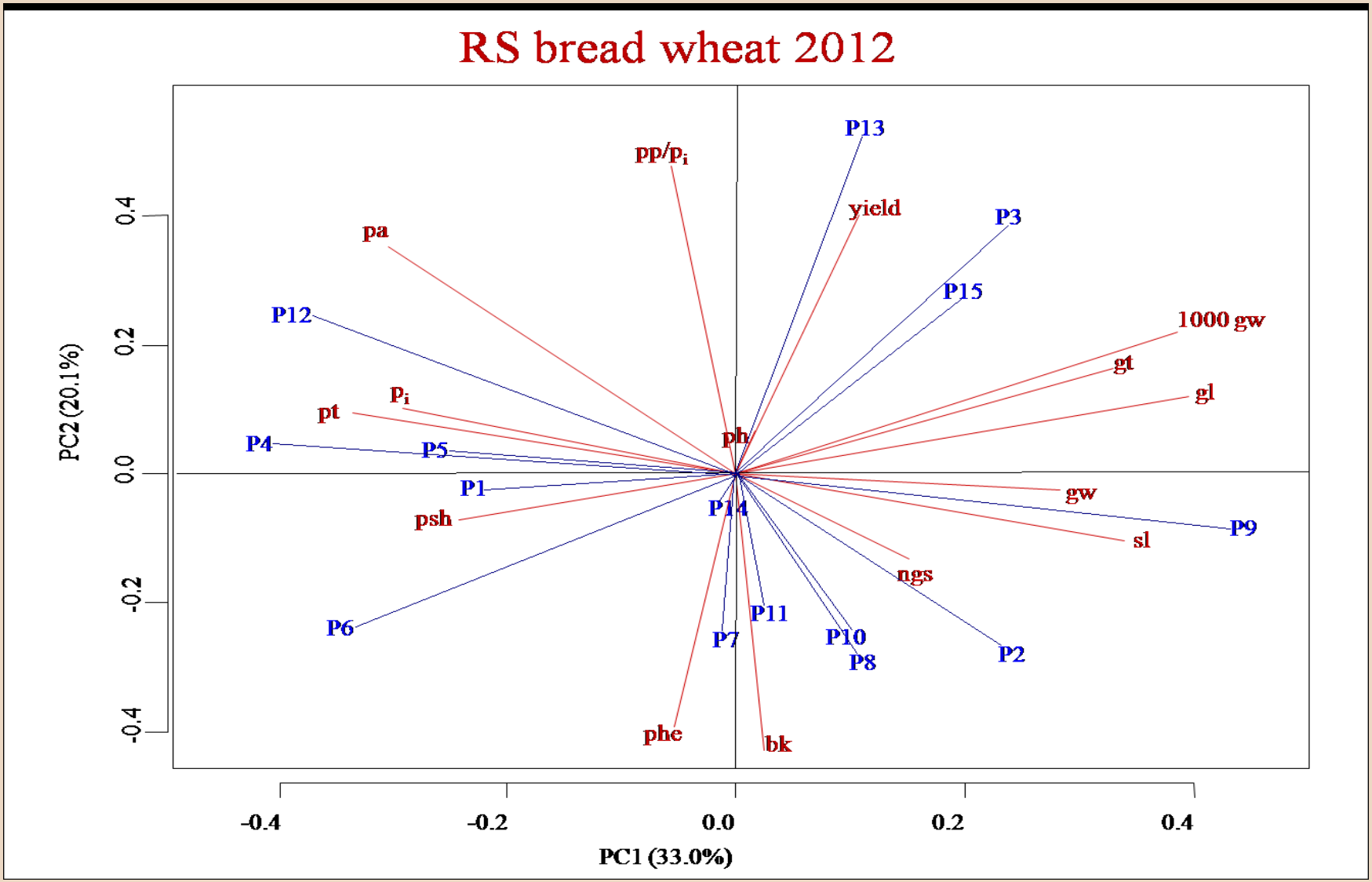


Figure 2. A genotype by trait (GT) biplot representing 15 bread wheat genotypes (P1-P15) measured for 9 agronomic and 6 chemical-technological traits for Rimski Sancevi location in 2012. (yield; 1000gw-thousand grain weight; ngs-number of grains per spike; ph-plant height; pt-productive tillering; sl-spike length; gt-grain thickness; gl-grain length; gw-grain width; phe-total phenols; bk-β-carotene; pa-phytic acid; p_i-inorganic phosphorus; pp/p_i-phytic acid phosphorus and inorganic phosphorus relation; psh-protein free sulfhydril groups.

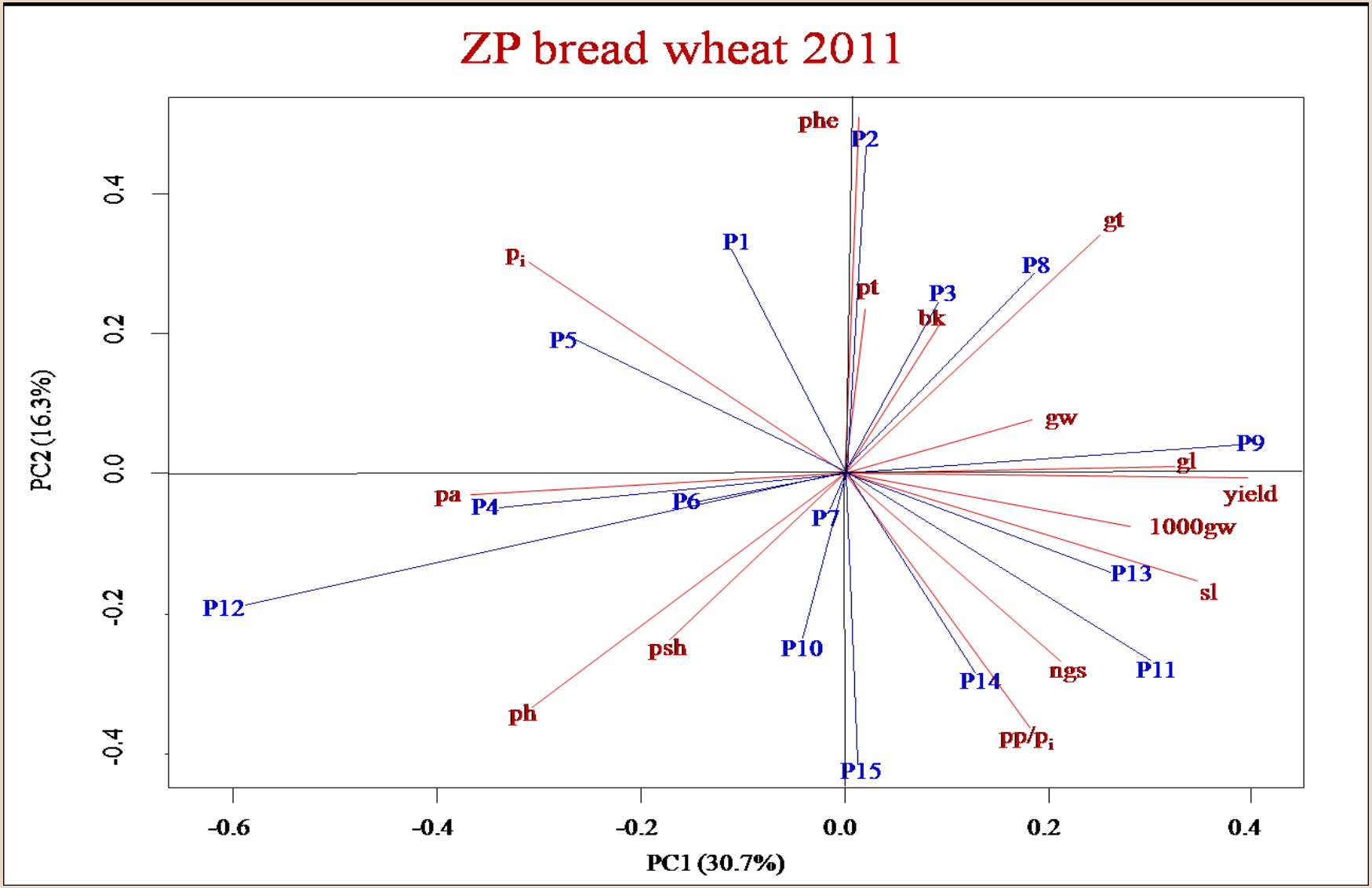


Figure 3. A genotype by trait (GT) biplot representing 15 bread wheat genotypes (P1-P15) measured for 9 agronomic and 6 chemical-technological traits for Zemun Polje location in 2011. (yield; 1000gw-thousand grain weight; ngs-number of grains per spike; ph-plant height; pt-productive tillering; sl-spike length; gt-grain thickness; gl-grain length; gw-grain width; phe-total phenols; bk-β-carotene; pa-phytic acid; p_i-inorganic phosphorus; pp/p_i-phytic acid phosphorus and inorganic phosphorus relation; psh-protein free sulfhydril groups.

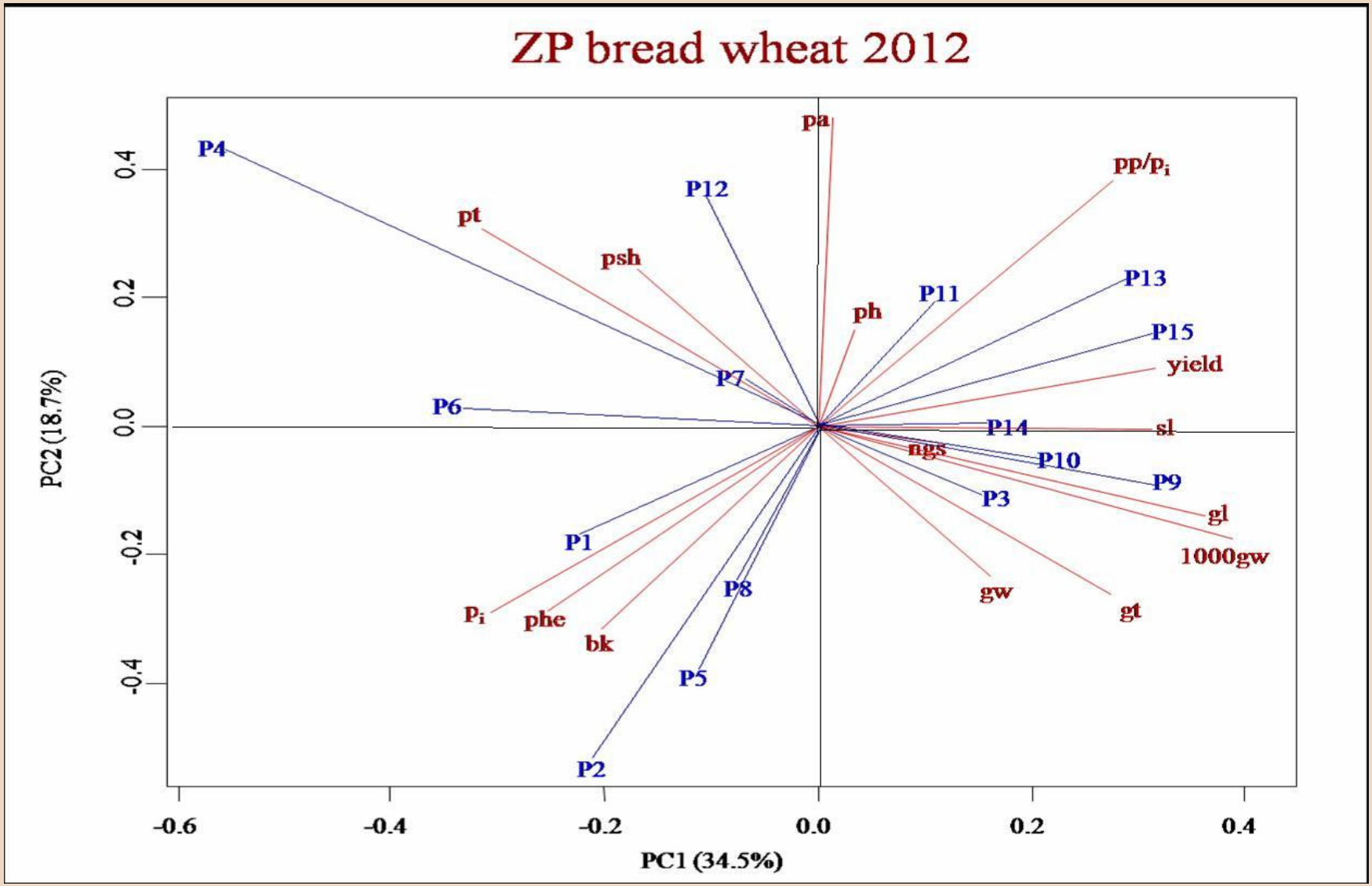


Figure 4. A genotype by trait (GT) biplot representing 15 bread wheat genotypes (P1-P15) measured for 9 agronomic and 6 chemical-technological traits for Zemun Polje location in 2012. (yield; 1000gw-thousand grain weight; ngs-number of grains per spike; ph-plant height; pt-productive tillering; sl-spike length; gt-grain thickness; gl-grain length; gw-grain width; phe-total phenols; bk-β-carotene; pa-phytic acid; p_i-inorganic phosphorus; pp/p_i-phytic acid phosphorus and inorganic phosphorus relation; psh-protein free sulfhydril groups.

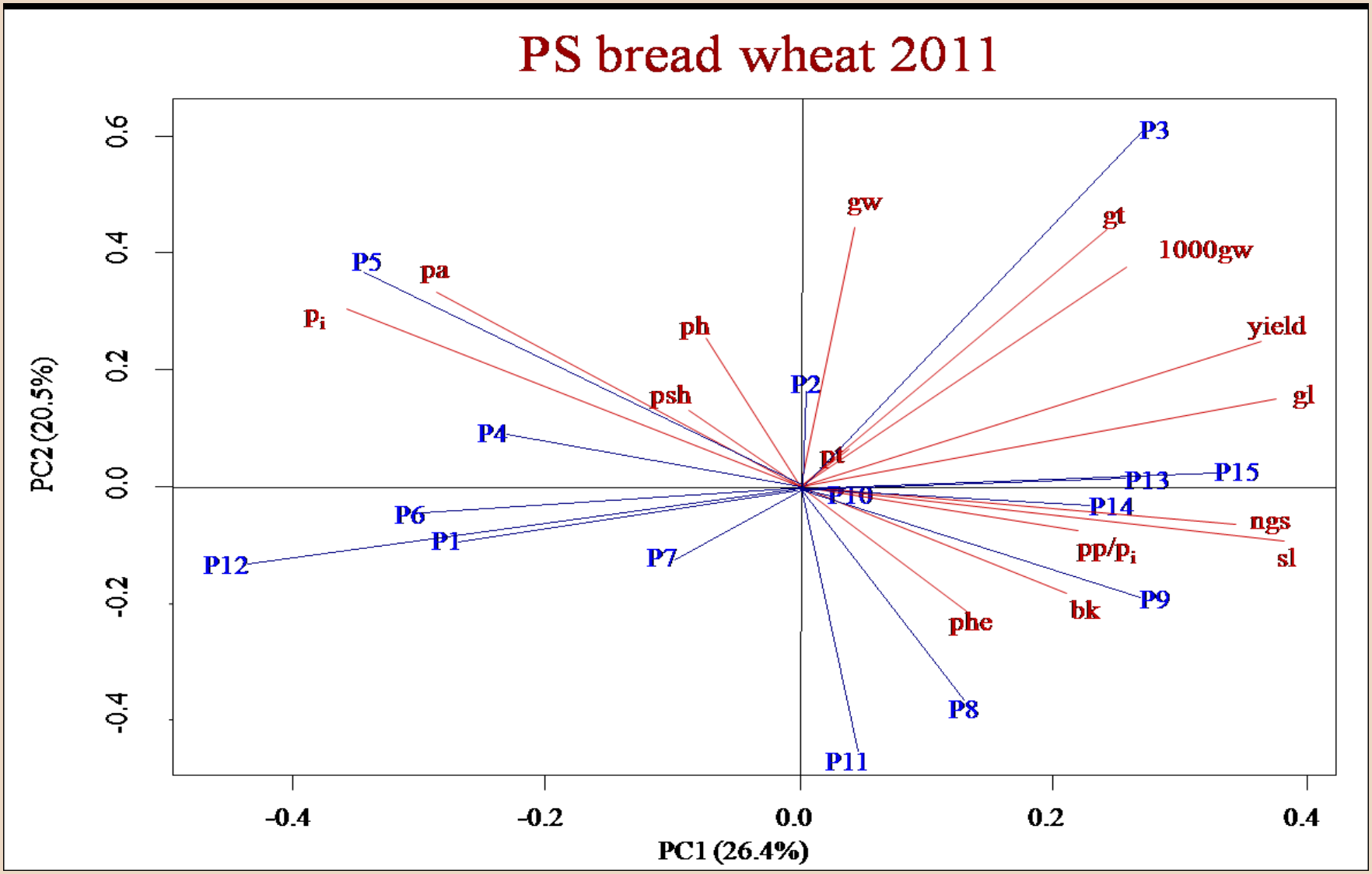


Figure 5. A genotype by trait (GT) biplot representing 15 bread wheat genotypes (P1-P15) measured for 9 agronomic and 6 chemical-technological traits for Padinska Skela location in 2011. (yield; 1000gw-thousand grain weight; ngs-number of grains per spike; ph-plant height; pt-productive tillering; sl-spike length; gt-grain thickness; gl-grain length; gw-grain width; phe-total phenols; bk-β-carotene; pa-phytic acid; p_i-inorganic phosphorus; pp/p_i-phytic acid phosphorus and inorganic phosphorus relation; psh-protein free sulfhydril groups.

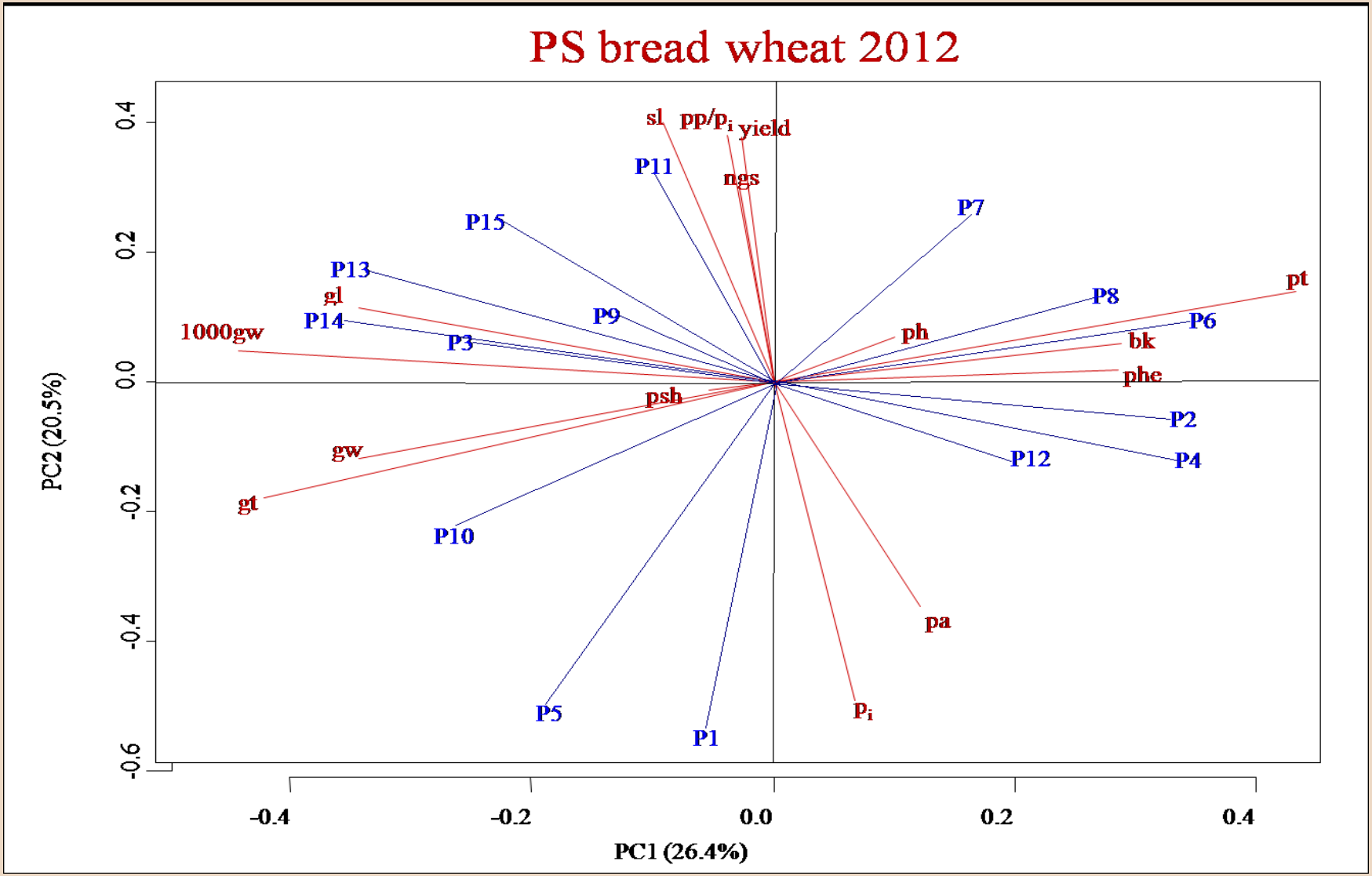


Figure 6. A genotype by trait (GT) biplot representing 15 bread wheat genotypes (P1-P15) measured for 9 agronomic and 6 chemical-technological traits for Padinska Skela location in 2012. (yield; 1000gw-thousand grain weight; ngs-number of grains per spike; ph-plant height; pt-productive tillering; sl-spike length; gt-grain thickness; gl-grain length; gw-grain width; phe-total phenols; bk-β-carotene; pa-phytic acid; p_i-inorganic phosphorus; pp/p_i-phytic acid phosphorus and inorganic phosphorus relation; psh-protein free sulfhydril groups.

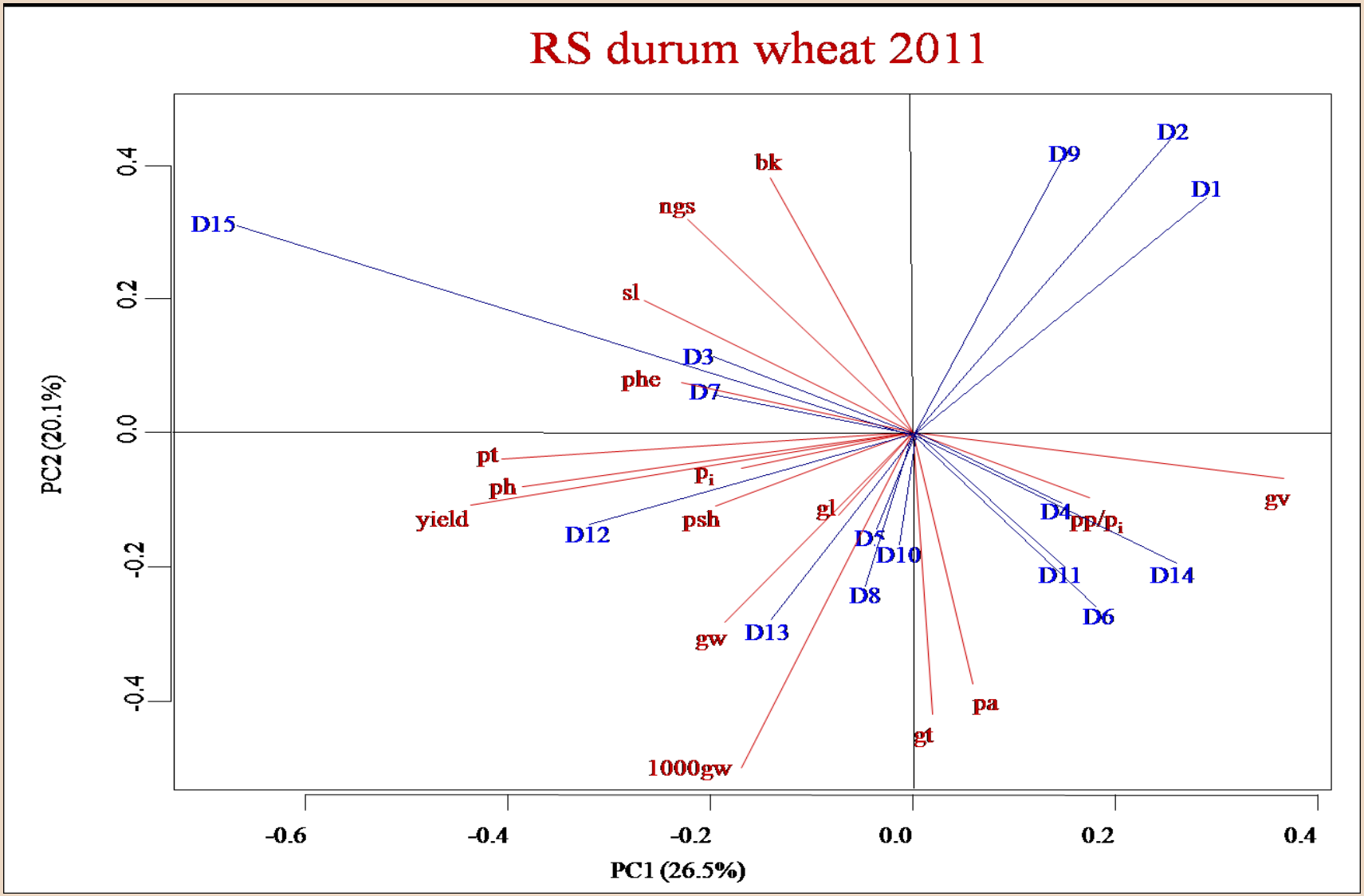


Figure 7. A genotype by trait (GT) biplot representing 15 durum wheat genotypes (D1-D15) measured for 9 agronomic and 7 chemical-technological traits for Rimski Sancevi location in 2011. (yield; 1000gw-thousand grain weight; ngs-number of grains per spike; ph-plant height; pt-productive tillering; sl-spike length; gt-grain thickness; gl-grain length; gw-grain width; phe-total phenols; bk-β-carotene; pa-phytic acid; p_i-inorganic phosphorus; pp/p_i-phytic acid phosphorus and inorganic phosphorus relation; psh-protein free sulfhydril groups, gv-grain vitreousness.

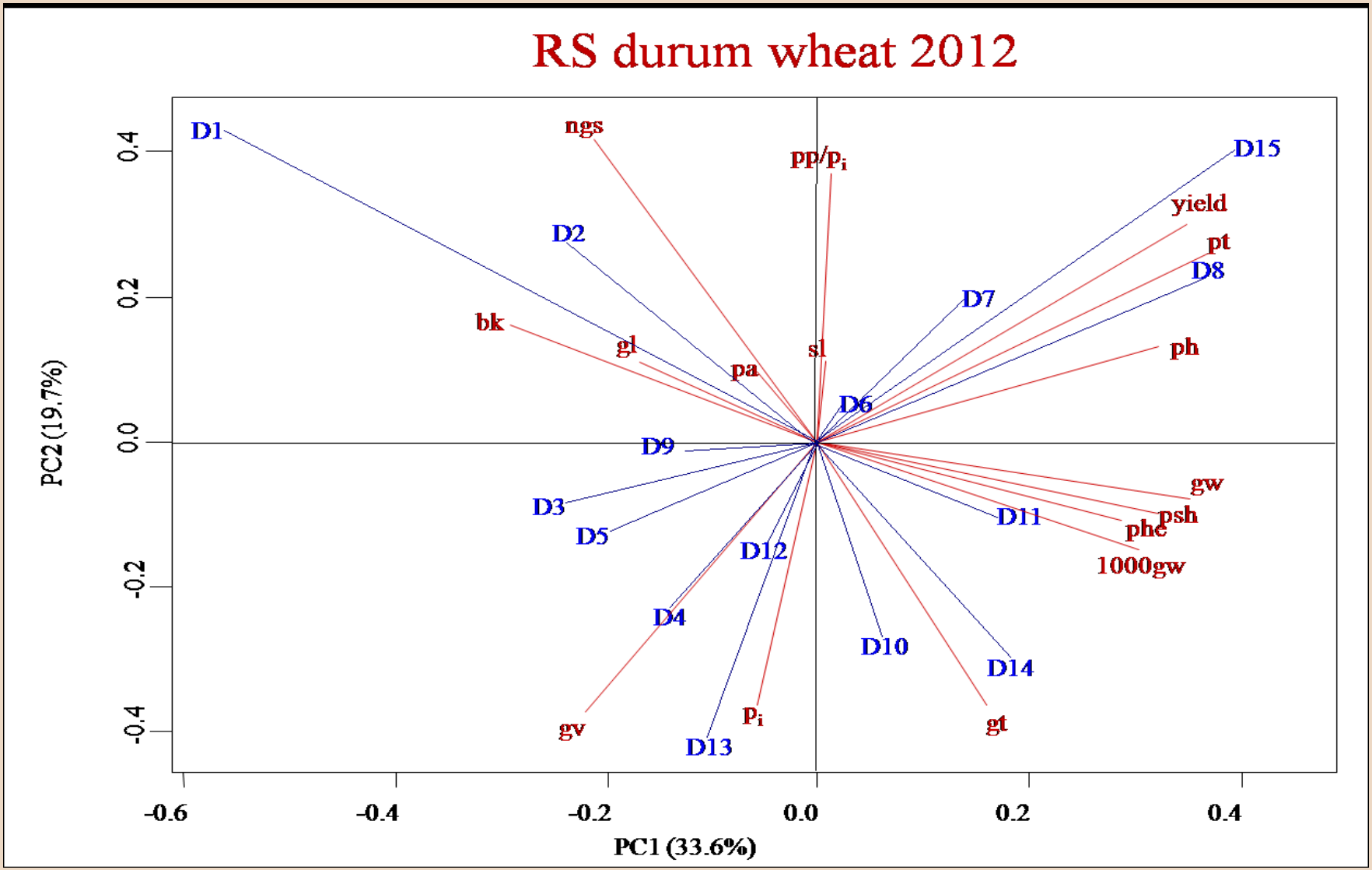


Figure 8. A genotype by trait (GT) biplot representing 15 durum wheat genotypes (D1-D15) measured for 9 agronomic and 7 chemical-technological traits for Rimski Sancevi location in 2012. (yield; 1000gw-thousand grain weight; ngs-number of grains per spike; ph-plant height; pt-productive tillering; sl-spike length; gt-grain thickness; gl-grain length; gw-grain width; phe-total phenols; bk-β-carotene; pa-phytic acid; p_i-inorganic phosphorus; pp/p_i-phytic acid phosphorus and inorganic phosphorus relation; psh-protein free sulfhydril groups, gv-grain vitreousness.

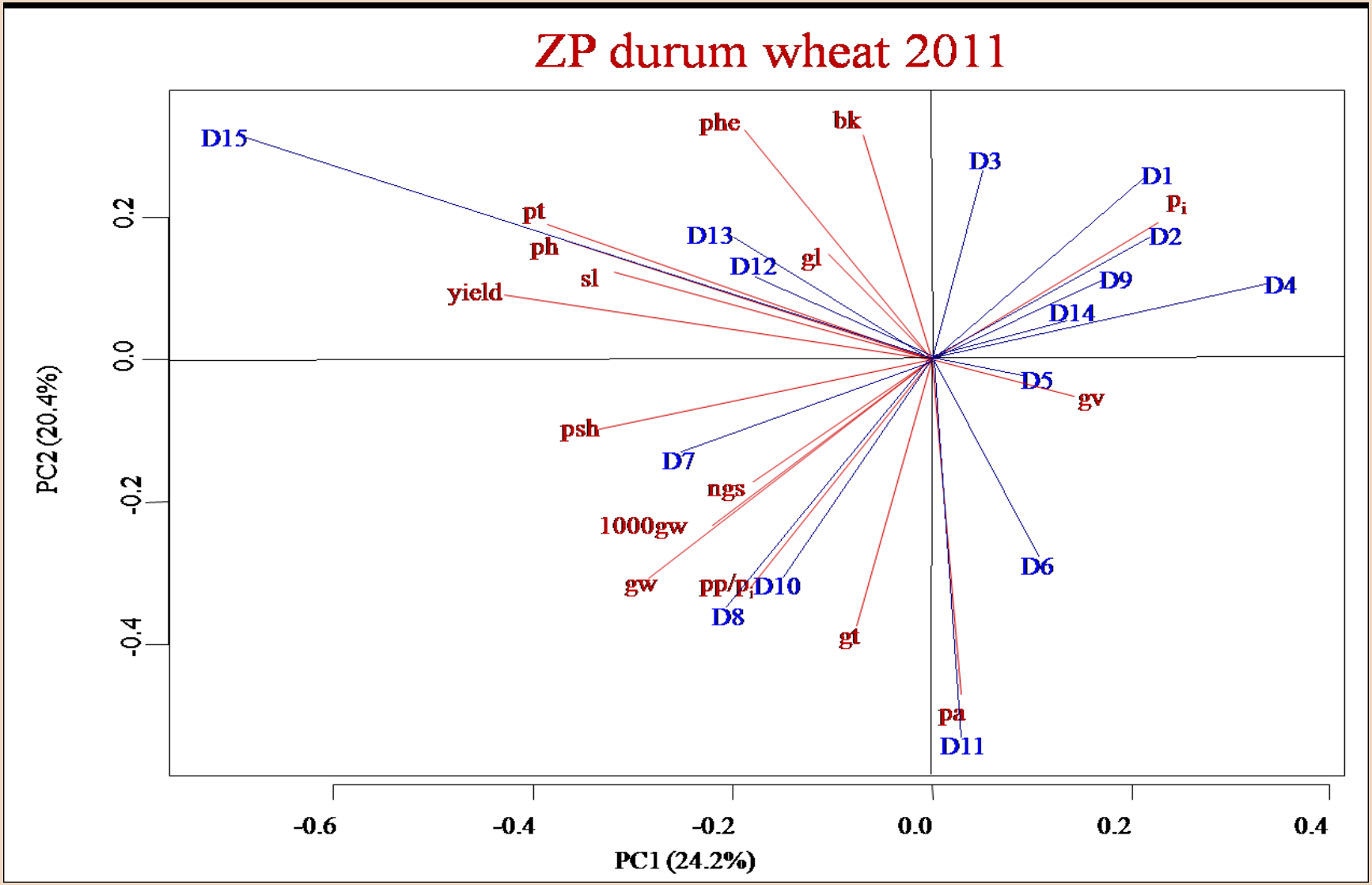


Figure 9. A genotype by trait (GT) biplot representing 15 durum wheat genotypes (D1-D15) measured for 9 agronomic and 7 chemical-technological traits for Zemun Polje location in 2011. (yield; 1000gw-thousand grain weight; ngs-number of grains per spike; ph-plant height; pt-productive tillering; sl-spike length; gt-grain thickness; gl-grain length; gw-grain width; phe-total phenols; bk-β-carotene; pa-phytic acid; p_i-inorganic phosphorus; pp/p_i-phytic acid phosphorus and inorganic phosphorus relation; psh-protein free sulfhydril groups, gv-grain vitreousness.

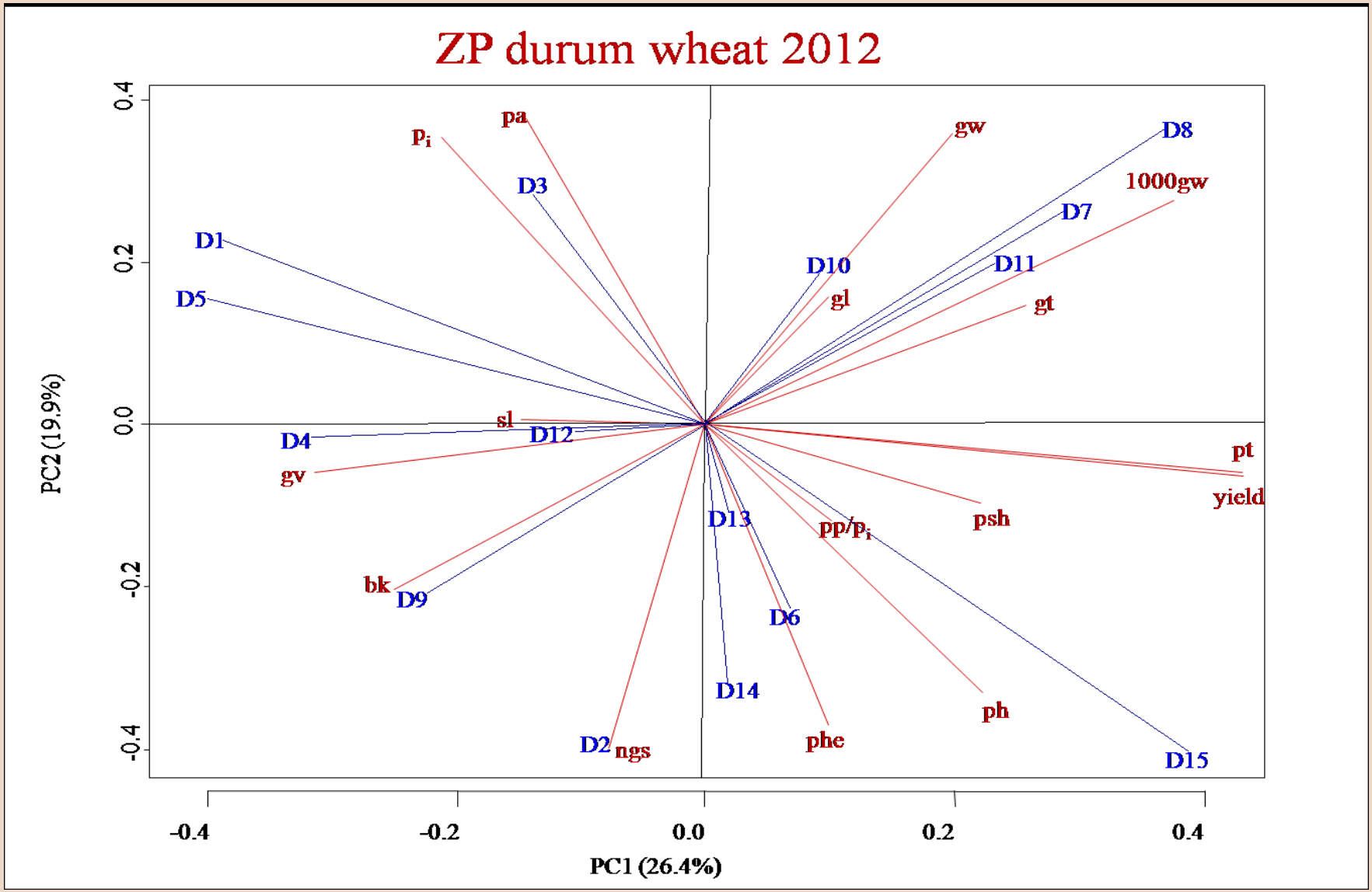


Figure 10. A genotype by trait (GT) biplot representing 15 durum wheat genotypes (D1-D15) measured for 9 agronomic and 7 chemical-technological traits for Zemun Polje location in 2012. (yield; 1000gw-thousand grain weight; ngs-number of grains per spike; ph-plant height; pt-productive tillering; sl-spike length; gt-grain thickness; gl-grain length; gw-grain width; phe-total phenols; bk-β-carotene; pa-phytic acid; p_i-inorganic phosphorus; pp/p_i-phytic acid phosphorus and inorganic phosphorus relation; psh-protein free sulfhydril groups, gv-grain vitreousness.

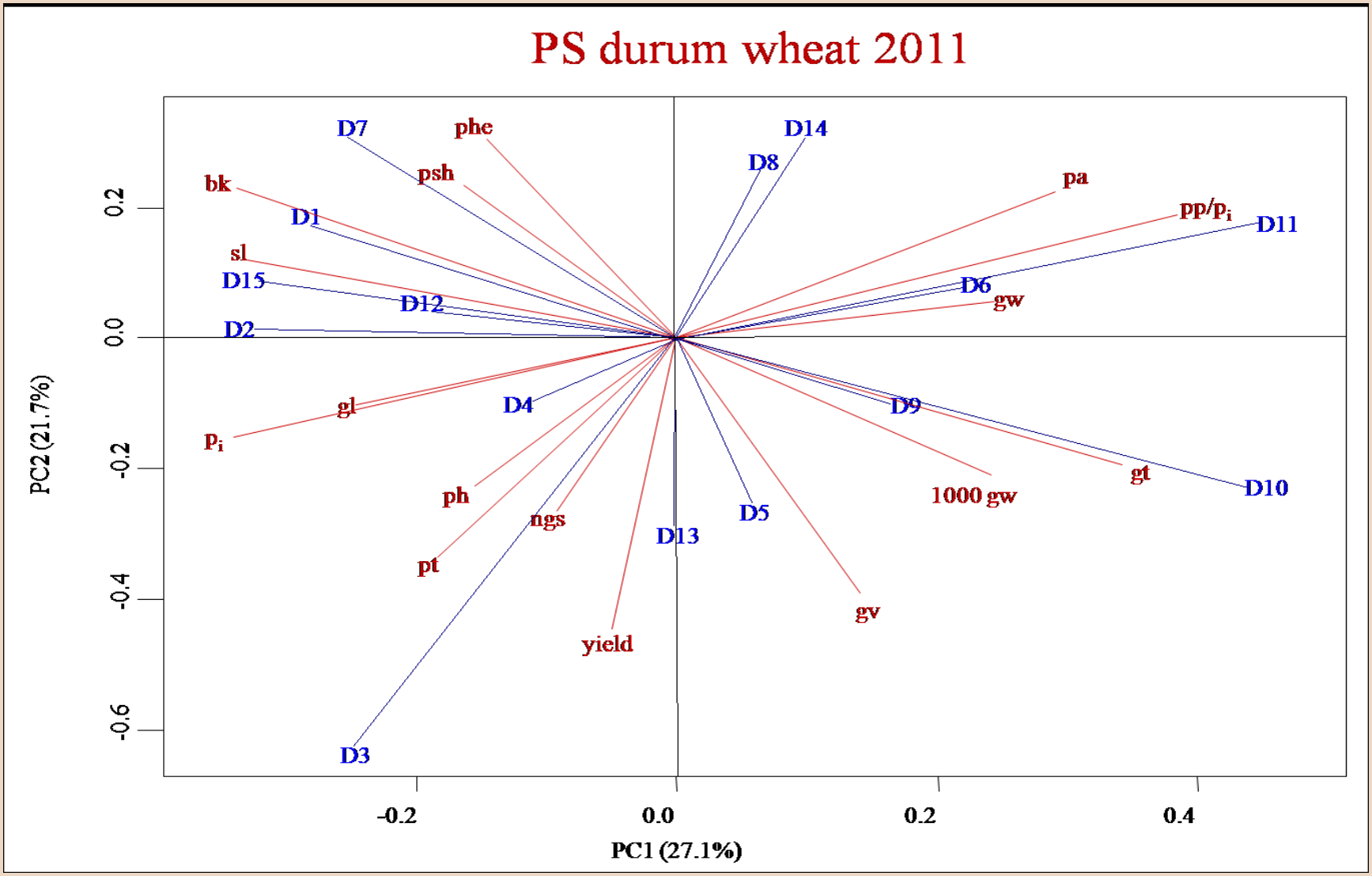


Figure 11. A genotype by trait (GT) biplot representing 15 durum wheat genotypes (D1-D15) measured for 9 agronomic and 7 chemical-technological traits for Padinska Skela location in 2011. (yield; 1000gw-thousand grain weight; ngs-number of grains per spike; ph-plant height; pt-productive tillering; sl-spike length; gt-grain thickness; gl-grain length; gw-grain width; phe-total phenols; bk-β-carotene; pa-phytic acid; p_i-inorganic phosphorus; pp/p_i-phytic acid phosphorus and inorganic phosphorus relation; psh-protein free sulfhydril groups, gv-grain vitreousness.

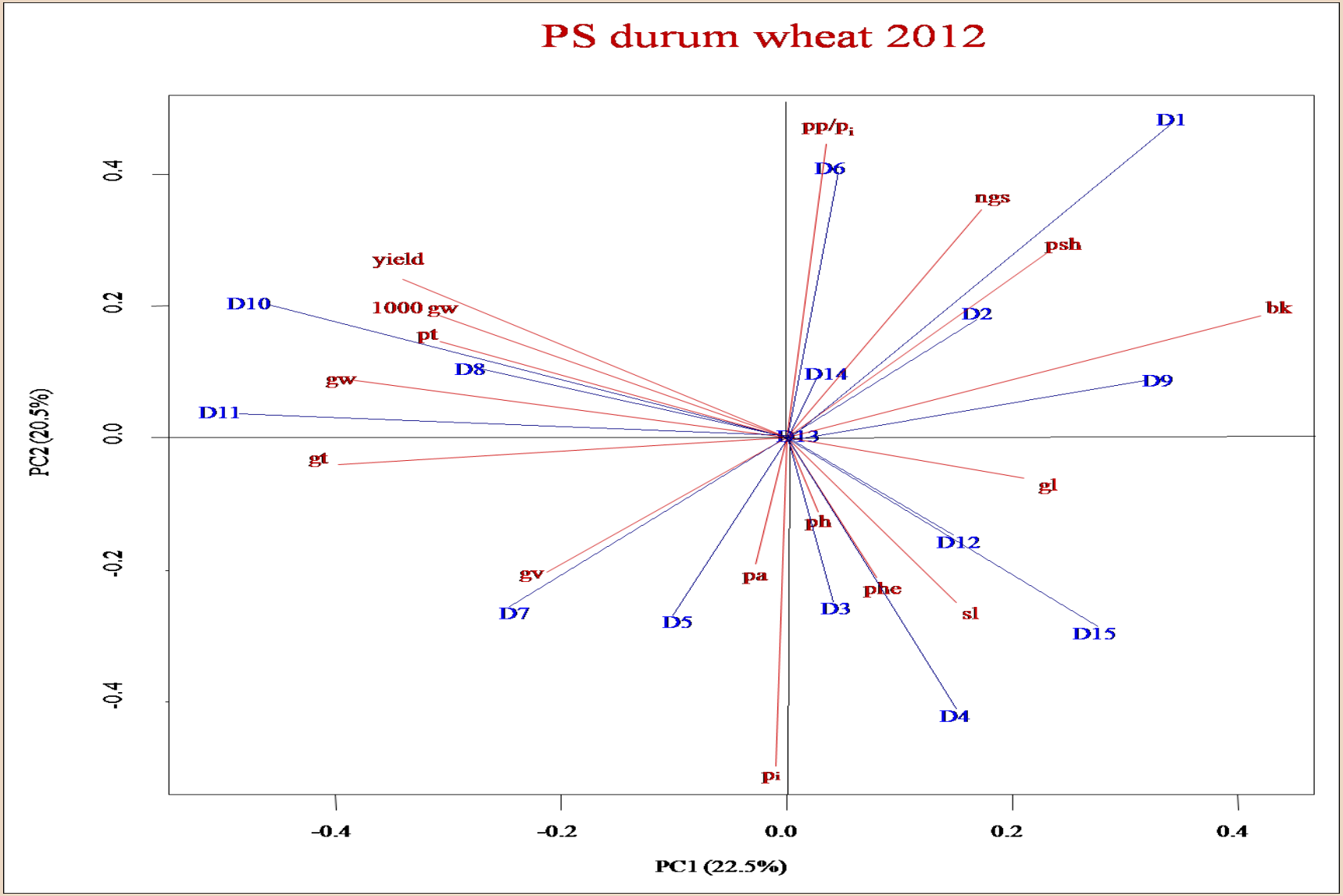


Figure 12. A genotype by trait (GT) biplot representing 15 durum wheat genotypes (D1-D15) measured for 9 agronomic and 7 chemical-technological traits for Padinska Skela location in 2012. (yield; 1000gw-thousand grain weight; ngs-number of grains per spike; ph-plant height; pt-productive tillering; sl-spike length; gt-grain thickness; gl-grain length; gw-grain width; phe-total phenols; bk-β-carotene; pa-phytic acid; p_i-inorganic phosphorus; pp/p_i-phytic acid phosphorus and inorganic phosphorus relation; psh-protein free sulfhydril groups, gv-grain vitreousness.

❑ Genotype by trait biplot (GT) analysis revealed existance of positive association between phenols and β-carotene (bread and durum wheat), phytic acid and PSH (bread wheat); phenols and PSH (durum wheat).

❑ Negative association was between phytic acid and β-carotene and with phenols (bread wheat), and also with all examined antioxidants (durum wheat). β-carotene and PSH were negatively associated for bread wheat and positively for durum wheat.

❑ Relation between PSH and phenols was more vague, and positive relationship existed in three environments, and negative in three, for bread wheat.

❑ Grain vitreousness was negatively associated with all examined antioxidants and positively with phytic acid (durum wheat).

❑ Grain yield had negative association with all examined antioxidants in bread wheat; and with β-carotene, phytic acid and grain vitreousness in durum wheat, and also positive with phenols and PSH, also in durum wheat. Relation between grain yield and phytic acid wasn’t consistent, in three environments was positive, and in three negative for bread wheat.

- Spike length was positively associated with β-carotene (bread and durum wheat), and with phenols (durum wheat).

- Plant height had positive relation with PSH and phytic acid (bread wheat), and with all examined antioxidants (durum wheat).

- Coefficient of productive tillering was positively associated with phytic acid (bread wheat), phenols and PSH (durum wheat).

- Grain length showed positive relation with all examined antioxidants (durum wheat).

- Number of grain per spike was positively associated with β-carotene and PSH (durum wheat). Also grain width and thickness and thousand grain weight were positively associated with PSH (durum wheat). Grain width and thickness were positively associated with phytic acid (durum wheat).

- Khan et al. (2007) found a statistically significant correlation between grain phytic acid content in bread wheat with grain width ($P < 0,001$), grain thickness ($P < 0,01$) and grain volume ($P < 0,05$). The existence of a positive correlation between phytic phosphorus content and free sulfhydryl groups of proteins of wheat (PSH) was reported ($r = 0,37$) (Lorenz et al., 2007).

- According to Aurang et al. (2006) thousand grain weight was statistically significantly correlated with the phytic acid content in early sowing ($P < 0,05$), while in late sowing statistically significant correlation ($P < 0,01$) of grain yield with the phytic acid content was established.

- Alvarez er al. (1999) found negative correlation between grain mass and β-carotene content in wheat ($r = -0,59$).

CONCLUSION

- Based on the GT analysis for the six environments the possibilities are deduced that could be used for breeding at improving the properties of phytic acid and antioxidants content. The favorable direction is in reducing phytic acid content and increasing the antioxidant content of genotypes of bread and durum wheat. Also, the genotypes were selected on the basis of good stability estimated by the AEC of the GGE biplot.

- The possibilities of studying the genetic determination of the phytic acid content and antioxidants content for genotypes of bread and durum wheat were also summarized. It was found that the hybridization of Stephens (low phytic acid) with the variety of Frankenmuth (high β-carotene and total phenols) could be useful for the integration of low phytic acid content and high content of β-carotene and total phenols in bread wheat descendants.

- The crosses of 37EDUYT / 07 No. 7849 or Varano (low phytic acid) with 34/ I or 10/I (high total phenols, PSH) might be useful for the incorporation of low phytic acid content and high phenolic content and PSH in the offspring of durum wheat. The hybridization which would attempt to enter the low phytic acid content and high content of PSH in bread wheat is impossible, due to determined consistent negative correlation among them across environments.

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Thank You For Your Attention!