GENOTYPE BY ENVIRONMENT INTERACTION FOR OIL QUALITY IN HIGH OLEIC ACID SUNFLOWER LINES

By

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SUMMARY

High oleic acid sunflower hybrids have been available on the market for a few years, but research on the stability of these genotypes for oil quality traits in South African production areas is limited. General aims of this study were to compare oil quality traits of high oleic sunflower against traditional sunflower genotypes in different environments, over seasons and under heat stress conditions and to identify possible genetic markers related to the oleic acid trait that would be useful in breeding programmes.

Combined ANOVAs of oil, linoleic, oleic, palmitic and stearic acid content of 16 genotypes tested in a total of nine trials over eight locations and three seasons showed highly significant differences between genotype, environment and GXE. Significant GXE suggested differential response of genotypes across testing locations and years and the need for stability analyses. Stability analyses were performed for all oil traits using AMMI. Stability analyses indicated that high oleic genotypes 6 and 8 could be considered stable across environments and seasons for oil and oleic acid content and genotype 9 for palmitic and stearic acid content.

Sunflower oil quality is affected by genotype and environmental conditions with temperature as a major influence. The effect of heat stress on seed yield and oil quality traits was investigated by applying a maximum temperature of 36°C to plants during the critical seed-filling stage. This information was needed to define a breeding strategy to further improve seed oil quality in environments where heat stress may occur. All traits measured were significantly influenced by heat stress. The low heritability estimates observed for seed-related yield traits indicated that genetic improvement for these traits would be difficult. Oil and linoleic acid contents were significantly reduced by heat, while oleic acid content was significantly increased in traditional hybrids. The oleic acid content of the high oleic acid hybrid was unaffected, but this hybrid showed the largest decrease in oil content. High heritability estimates observed for oleic and linoleic acid content indicated that it is possible to genetically improve these traits under different temperature conditions.

Since oleic acid content is influenced by the environment, this trait showed instability across environments. Genotypic selection for this trait using linked markers is independent from the environment. A segregating population comprising 78 F_2 individuals was obtained from a cross between a high oleic acid and traditional sunflower line. AFLP and SSR markers were used to identify and map QTL, associated with the high oleic acid trait, putatively to LG 14 of the sunflower consensus map. A major QTL controlling the level of oleic acid was identified that explained 35% of the phenotypic variance for this trait. Markers linked to this trait were identified that could be useful in MAB.

Physicochemical properties and oxidative stability of seed oil of high (82.6% oleic) and mid oleic acid (53.8% oleic) sunflower hybrids were compared with those of traditional sunflower (65.7% linoleic and 22.9% oleic). Oxidative stability was evaluated by measuring PV, *p*-AV and OSI values. High oleic acid oil had the best oxidative stability. Since oxidative stability was related to the unsaturation level of oil, the high oleic oil with significantly reduced linoleic acid content had the highest resistance to oxidation. Keeping quality of commercially available vegetable oils, including high oleic sunflower oil was evaluated using the Schaal oven test. Oil samples, placed in a heat cabinet at 63°C were periodically examined for keeping quality by determining PV, *p*-AV and RI values. High oleic sunflower oil was twice as stable as traditional sunflower and canola oils.

Keywords: AMMI, ANOVA, broad sense heritability, high oleic acid, fatty acids, molecular markers, *Helianthus annuus* L., oxidative stability, temperature stress

OPSOMMING

Hoë-oleïensuur sonneblombasters is al vir 'n geruime tyd kommersieel beskikbaar, maar byna geen navorsing is gedoen om die stabiliteit van hierdie genotipes ten opsigte van olie-kwaliteitseienskappe in Suid-Afrikaanse produksiegebiede te ondersoek nie. Die doel van hierdie studie was om die olie-kwaliteitseienskappe van Suid-Afrikaanse hoë-oleïensuur sonneblomgenotipes met dié van tradisionele sonneblomgenotipes te vergelyk en om die effek van verskillende omgewings, seisoene en temperatuurstoestande op hierdie genotipes te bepaal. 'n Verdere doel was om moontlike molekulêre merkers, wat aan die hoë-oleïeneienskap gekoppel is en in teelprogramme gebruik kan word, te identifiseer.

Die gekombineerde variansie-analises vir palmitiensuur, steariensuur, oleïensuur, linoliensuur en olie-inhoud het aangetoon dat vir 'n totaal van 16 genotipes, wat in nege proewe in agt lokaliteite oor 'n tydperk van drie jaar ontleed is, daar hoogs betekenisvolle verskille vir genotipe, omgewing en genotipe-omgewing interaksie was. Betekenisvolle genotipe-omgewing interaksie het aangetoon dat genotipes verskillend in verskillende omgewings en oor jare gereageer het en stabiliteitsontledings was dus nodig. Die stabiliteit van al die olie-eienskappe is deur middel van additiewe hoofeffek en multiplikatiewe en interaksie analise (AMMI) bepaal. Hierdie ontledings het aangetoon dat die hoë-oleïensuur genotipes 6 en 8 hoogs stabiel oor omgewings en seisoene was vir olie- en oleïensuurinhoud, terwyl genotipe 9 stabiel vir palmitiensuur- en steariensuurinhoud was.

Sonneblomolie-kwaliteit word grootliks deur die omgewing beïnvloed en temperatuur speel die belangrikste rol. Die effek van hittestremming op saadopbrengs- en olie-kwaliteiteienskappe is bestudeer deur sonneblomplante aan 'n maksimum temperatuur van 36°C gedurende die mees kritieke stadium van lipiedbiosintese bloot te stel. Hittestremming het 'n betekenisvolle invloed op al die eienskappe gehad. Lae oorerflikhede van saadopbrengs-verwante eienskappe dui daarop dat genetiese vordering vir hierdie eienskappe nie haalbaar is nie. Vir die tradisionele sonneblombasters is 'n betekenisvolle afname in linoliensuur waargeneem, terwyl oleïensuurinhoud betekenisvol toegeneem het. Die oleïensuurinhoud van die hoë oleïenbaster was onveranderd, maar hierdie baster het 'n beduidende afname in olie-inhoud getoon. Die hoë oorerflikhede vir

oleïensuur en linoliensuur dui daarop dat dit wel moontlik sal wees om hierdie eienskappe geneties onder verkillende temperatuurtoestande te verbeter.

Omdat oleïensuurinhoud grootliks deur omgewingstoestande beïnvloed word, is hierdie eienskap onstabiel oor verskillende omgewings. Deur van genetiese merkers wat aan die hoë-oleïeneienskap gekoppel is, gebruik te maak, kan seleksie op die genotipe gedoen word en die omgewing speel dus nie 'n rol nie. 'n F_2 segregerende populasie, bestaande uit 78 plante, is verkry nadat 'n hoë-oleïen ingeteelde lyn met 'n tradisionele sonneblomteellyn gekruis is. AFLP (geamplifiseerde fragment lengte polimorfisme)- en SSR (eenvoudig herhalende volgorde) analises is gebruik om QTL (kwantitatiewe eienskap lokusse), wat aan die hoë-oleïeneienskap gekoppel is, te identifiseer en waarskynlik op LG 14 van die konsensus sonneblomkaart te karteer. 'n Hoof QTL, wat die hoë-oleïensuur inhoud reguleer, is geïdentifiseer en verklaar 35% van die fenotipiese variasie vir hierdie eienskap. Die geïdentifiseerde merkers, wat aan die hoë-oleïeneienskap gekoppel is, kan vir merker-ondersteunende teling gebruik word.

Die fisies-chemiese- en oksidatiewe stabiliteitseienskappe van die saadolie van hoë-oleïensuur (82.6% oleïensuur) en mid-oleïensuur (53.8% oleïensuur) sonneblombasters is met dié van tradisionele sonneblom (65.7% linoliensuur en 22.9% oleïensuur) vergelyk. Oksidatiewe stabiliteit is bepaal deur peroksied-, *p*-ansidien- en olie stabiliteitsindeks (OSI) waardes te meet. Olie van die hoë-oleïensuurbasters het die beste weerstand teen oksidasie getoon. Omdat die vetsuur-onversadigingsvlak van olie 'n aanduiding van oksidatiewe stabiliteit is, het die hoë-oleïenolie, wat die laagste onversadigingsvlak gehad het, die meeste weerstand teen oksidasie getoon. Die oksidatiewe stabiliteit van kommersiële kookolies, insluitende dié van hoë-oleïen sonneblom olie, is deur middel van die Schaal oondtoets geëvalueer. Olie monsters is in 'n hittekabinet by 63°C geplaas en peroksied-, *p*-ansidien- en refraksie indekswaardes is gereeld geneem om te bepaal hoe lank dit vir die olie neem om te oksideer. Die oksidatiewe stabiliteit van die hoë-oleïen sonneblom olie was twee maal hoër as dié van tradisionele sonneblom- en kanola-olie.

Kernwoorde: AMMI, ANOVA, oorerflikheid in die breë begrip, hoë oleïensuur, vetsure, molekulêre merkers, *Helianthus annuus* L., oksidatiewe stabiliteit, temperatuurstremming