**Table S4: Putative candidate genes and function of the root bulking traits at different plant age**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **MAP** | | **SNP** | **Chr** | **Position** | **Putative candidate gene** | **Gene description** | **Function of candidate gene** |
| **Dry Matter Content** | | | | | | | |
| 3 | S5\_1557006 | | 5 | 1557006 | LOC110615655 MANES\_05G016400v8 | Conserved oligomeric Golgi complex subunit 4 | * Important for intracellular transport and glycoprotein modification; * Important for plant defense against directly penetrating fungal pathogens at the root cell. |
| 3 | S5\_1557006 | | 5 | 1557006 | LOC110615708 MANES\_05G016500v8 | Pyruvate dehydrogenase E1 component subunit alpha-3, chloroplastic | * Serves as the main connection between glycolysis and the tricarboxylic acid (TCA) cycle. * Plays a role in the processes that transform the energy from food into a form that cells can use. |
| 3 | S10\_2912754 | | 10 | 2912754 | LOC110624725 MANES\_10G029000 | Actin-related protein 5 | * Control the growth of roots. * Controls several aspects of plant morphogenesis and development, including the biological process that regulates root meristem growth. |
| 3 | S2\_5069109 | | 2 | 5069109 | LOC110608741 MANES\_02G065900v8 | Protein GAMETE EXPRESSED 3 | Overexpression inhibits root cell growth |
| 3 | S2\_5069109 | | 2 | 5069109 | LOC110610187 MANES\_02G066100v8 | Cyclin-B1-2 | * Lengthens roots more. * The growth of lateral roots and enlargement of root tips. * Influence root microtubule changes. |
| 3 | S2\_10059232 | | 2 | 10059232 | LOC110609871 MANES\_02G066400v8 | Transcription factor CYCLOIDEA | * Play versatile functions in multiple aspects of plant growth and development. * Help in development of diverse organs via the cell cycle |
| 3 | S2\_10059232 | | 2 | 10059232 | LOC110609847 MANES\_02G066500v8 | Small polypeptide DEVIL 3 | * Coordinating cellular responses necessary for differentiation, growth, and development by acting as a regulatory molecule. * Regulators of plant physiology, growth, and development. |
| 6 | S10\_2319500 | | 10 | 2319500 | LOC110624967 | PRA1 family protein A3-like | * Help in role of root growth and development. * Overexpression significantly promotes root growth. * Accelerated growth and significantly increase root length. |
| 6 | S10\_2319500 | | 10 | 2319500 | LOC122724935, LOC110624553, MANES\_10G023900v8 MANES\_10G024026v8 | Receptor-like protein 9DC3 | Increases the surface area of a root and maximizes its ability to absorb water and inorganic nutrients essential for plant growth and development. |
| 6 | S2\_1937678 | | 2 | 1937678 | LOC110609737 MANES\_02G021900v8 | Kinesin-like protein KIN-14J | **Transcription activation activity in regulating gibberellin biosynthesis and cell growth** |
| 6 | S2\_1937678 | | 2 | 1937678 | LOC110609329 MANES\_02G022100v8 | Serine/threonine-protein kinase BSK7 | * Required for plants to withstand the stress of drought. * Important plant hormone that controls cellular functions like growth, development, and abiotic stress defense responses. * Regulates the transfer of ions in guard cells. * Plants can withstand the effects of drought stress thanks to decreased transpirational water loss. |
| 6 | S3\_3324735 | | 3 | 3324735 | LOC110610259 MANES\_03G037700v8 | Alpha/beta hydrolase domain-containing protein WAV2 | Modulates root bending in response to environmental stimuli |
| 6 | S3\_3324735 | | 3 | 3324735 | LOC110612221 MANES\_03G037800v8 | Phospholipid:diacylglycerol acyltransferase 1 | Play an overlapping roles in triacylglycerol (TAG) assembly  Contributes to TAG accumulation. |
| 6 | S3\_3324735 | | 3 | 3324735 | LOC110612414 MANES\_03G037600v8 | protein PLASTID MOVEMENT IMPAIRED 1-RELATED 1 | Play important roles in fundamental cellular activities and adaptive responses to environmental stress in plants. |
| 6 | S3\_3324735 | | 3 | 3324735 | LOC110612104 MANES\_03G037900v8 | Protein Brevis radix-like 4 | Identified as a modulator of root growth. |
| 6 | S3\_3324735 | | 3 | 3324735 | LOC110611194 MANES\_03G038000v8 | protein BIG GRAIN 1-like A | * Plays a role in grain development, plant growth, and gravitropism. * Increase plant yield, seed weight, and biomass. * Expands the size of the main organs and roots. * A crucial developmental protein used in the construction of the roots. * Take part in stress tolerance and yield component regulation |
| 6 | S3\_3324735 | | 3 | 3324735 | LOC110612102 MANES\_03G038200v8 | RING-H2 finger protein ATL1 | Play significant roles in plant growth, development, stress resistance, and signal transduction. |
| 6 | S3\_3324735 | | 3 | 3324735 | LOC110610463 MANES\_03G038300v8 | Mechanosensitive ion channel protein 10 | Diverse roles in the formation of pollen tubes, control of plastid shape, seed germination, and root development in plants. |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Dry Yield** | | | | | | | | |
| 6 | S6\_19749539 | | 6 | | 19749539 | LOC110618340 MANES\_06G063000v8 | protein DETOXIFICATION 14 | Involved in nitrogen detoxification Impact on Protein Synthesis and Root Development in Cassava Roots. |
| 6 | S6\_19749539 | | 6 | | 19749539 | LOC110617342 MANES\_06G062900v8 | ATP synthase subunit beta, mitochondrial | * Synthesizes the main bulk of cytosolic ATP. * Converts the electrochemical proton gradient into ATP. |
| 6 | S17\_18894518 | | 17 | | 18894518 | LOC110604801 MANES\_17G023800v8 | Probable prolyl 4-hydroxylase 6 | * Catalyze an important post-translational modification in plants**.** * Required for proper cell wall self-assembly and hence root hair elongation |
| 6 | S17\_18894518 | | 17 | | 18894518 | LOC110605470 MANES\_17G023900v8 | Transcription factor MYB35 | * Controls root epidermal cell specification. * Inhibit root hair (RH) formation by activating the GL2 gene expression. |
| 6 | S17\_13553658 | | 17 | | 13553658 | LOC110605409 MANES\_17G022300v8, LOC110605499, MANES\_17G022600v8 | V-type proton ATPase subunit d2. | * Required for efficient nutrient storage. * Plays an important role in plant growth |
| 6 | S17\_13553658 | | 17 | | 13553658 | LOC110605174 MANES\_17G022200v8 | Probable E3 ubiquitin ligase complex SCF subunit sconB | A variety of biological processes, including hormonal Control of biotic and abiotic stress tolerance, light response, plant reproduction, vegetative development, and DNA repair |
| 6 | S4\_26245979 | | 4 | | 26245979 | LOC110613858 MANES\_04G065900v8 | Endochitinase | Play a part in the processes of defense, growth, and development.  Boost plant output and growth. |
| 6 | S4\_26245979 | | 4 | | 26245979 | LOC110613855 MANES\_04G066000v8 | Probable inactive chitinase-like protein LaCIC | Play multiple roles in defense, development and growth regulation in plants. |
| 12 | S4\_8840623 | | 4 | | 8840623 | LOC110612547  MANES\_04G050700v8 | Diazcylglycerol lipase-beta | * Enhance membrane stability. * Function in stress tolerance and the provision of substrates for the biosynthesis of bioactive compounds. |
| 12 | S4\_8840623 | | 4 | | 8840623 | LOC110613962 MANES\_04G054500v8 | Transcription factor bHLH128 | * Control the plant's adaptive reactions * Impact on the development and production of important crops. * In closed chromatin, crucial elements for cellular reprograming are often found. |
| 12 | S18\_3834291 | | 18 | | 3834291 | LOC110607026 MANES\_18G043300v8 | Agamous-like MADS-box protein AGL66 | * Control of lateral organ development and flowering time. * Regulates root meristem cell division and promotes overall root vascular tissue formation |
| 12 | S18\_3834291 | | 18 | | 3834291 | LOC110606009 MANES\_18G043400v8 | E3 ubiquitin-protein ligase APD2 | * Importance in controlling cellular functions. * Control plant development and growth * Developed a wide range of intricate adaptive mechanisms to deal with unfavorable environmental circumstances, including as the preservation of ion homeostasis, accumulating antioxidant enzymes, and producing suitable products. |
| 12 | S18\_3834291 | | 18 | | 3834291 | LOC110606409 MANES\_18G043200v8 | Putative cyclin-A3-1 | Cell cycle regulation, cell death control, and DNA repair |
| 12 | S18\_3834291 | | 18 | | 3834291 | LOC110606712 MANES\_18G043000v8 | Cytochrome P450 81C13 | * It aids in carotenoid pigment formation, which is important for photosynthesis and photoprotection. * Assuring mechanical support, water retention, and transport by serving as the building blocks for structural biopolymers such lignin, suberin, cutin, and sporopollenin. * Participate in the growth, development, or fitness of plants. |
| **Fresh Root Yield** | | | | | | | | |
| 6 | | S18\_9930952 | | 18 | 9930952 | LOC110605839 MANES\_18G103400v8 | DEAD-box ATP-dependent RNA helicase FANCM. | * Involved in ordered homologous recombination (HR) events in somatic and meiotic cells. * Involved in the suppression of spontaneous HR events in somatic cells. * Associate with a diverse range of cellular functions including response to abiotic stress. |
| 6 | | S18\_9930952 | | 18 | 9930952 | LOC110606107 MANES\_18G103600v8 | Transcription factor MYB8 | * Involved in the regulation of secondary wall biosynthesis. * Activate the biosynthetic pathways of cellulose, xylan and lignin. |
| 12 | | S4\_8840623 | | 4 | 8840623 | LOC110614192 MANES\_04G053400v8 | Galactolipase DONGLE, chloroplastic | Play pivotal roles during plant developmental processes, such as seed maturation, viable pollen production, root growth, and tendril coiling, and they also function as important signaling molecules in plant defense responses to biotic and abiotic stress. |
| 12 | | S4\_8840623 | | 4 | 8840623 | LOC110612547 MANES\_04G050700v8 | Diacylglycerol lipase-beta | * Enhance membrane stability. * Function in stress tolerance and the provision of substrates for the biosynthesis of bioactive compounds. |
| **Harvest Index** | | | | | | | | |
| 3 | | S14\_4092696 | | 14 | 4092696 | LOC110600339 MANES\_14G047200v8 | Proteasome subunit alpha type-4 | Increased cell sizes, decreased heat shock tolerance, increased oxidative stress tolerance. |
| 12 | | S10\_2601853 | | 10 | 2601853 | LOC110630745 MANES\_14G047100v8 | Ubiquitin-conjugating enzyme E2 27 | Important role in plant development, growth, and external stress responses |
| 12 | | S10\_2601853 | | 10 | 2601853 | LOC110600271 MANES\_14G046800v8 | CASP-like protein 1F1. | * Genes involved in plant defense as well as growth promotion and regulation of specific processes (flowering, photosynthesis, glucose catabolism, and root growth). * Increasing plant weight, crop yield, and seed germination |
| 12 | | S10\_2601853 | | 10 | 2601853 | LOC110624115 MANES\_10G026300v8 | Protein HESO1 | Help in root architecture, root length and root hairs development. |
| 12 | | S10\_2601853 | | 10 | 2601853 | LOC110624114 MANES\_10G026200v8 | Probable methyltransferase PMT11 | Several secondary metabolites, such as phenylpropanoids, flavonoids, and alkaloids, methylate the oxygen atom. |
| 12 | | S10\_2601853 | | 10 | 2601853 | LOC110624586, MANES\_10G026500v8, LOC110625324 MANES\_10G026600v8 | Tropinone reductase homolog At5g06060 | Predominantly trigger signals for plant development |
| 12 | | S10\_2601853 | | 10 | 2601853 | LOC110625187 MANES\_10G026400v8 | Protein phosphatase 2C 37 | Function as regulators of various signal transduction pathways. |
| 12 | | S10\_2601853 | | 10 | 2601853 | LOC110624973 MANES\_10G025950v8 | BTB/POZ and MATH domain-containing protein 3 | Involved in plant growth and development. |
| 12 | | S10\_2601853 | | 10 | 2601853 | LOC110625323 MANES\_10G026700v8 | Receptor-like protein Cf-9 homolog | Play key roles in **plant** defense and development |
| 12 | | S10\_2601853 | | 10 | 2601853 | LOC110624466 MANES\_10G024900v8 | CASP-like protein 5B2 | * In root systems is involved in stress resistance and maintaining homeostasis. * Regulatory role on lateral root growth and development |
| **Storage root size** | | | | | | | | |
| 9 | | S9\_26051761 | | 9 | 26051761 | LOC110608208 MANES\_09G090321v8 | Type I inositol polyphosphate 5-phosphatase 8. | * Functions in various aspects of plant growth and development. * Required for secondary wall synthesis and actin organization in fiber cells |
| 9 | | S9\_26051761 | | 9 | 26051761 | LOC122724719 | Small nucleolar RNA R71. | Manipulate plant metabolites, develop plants with improved resistance to environment stresses, and engineer plants to defend against pathogen infections. |
| 9 | | S5\_12439769 | | 5 | 12439769 | LOC110615234 MANES\_05G118900V8 | Pentatricopeptide repeat-containing protein At4g20740 | Involved in RNA regulation and metabolism in plant organelles. |
| LOC110615220 MANES\_05G118701v8 | Uncharacterized protein |  |
| 9 | | S2\_4134534 | | 2 | 4134534 | LOC110609508 MANES\_02G051800v8 | Probable galacturonosyltransferase 13 | * Function redundantly in pollen tube growth, possibly via taking part in pectin biosynthesis of the pollen tube wall. * Catalyzes the elongation of HG oligogalacturonides in a -1, 4-configuration.. |
| 9 | | S2\_4134534 | | 2 | 4134534 | LOC110608705 MANES\_02G051600v8 | Chaperone protein ClpB3, chloroplastic | * Important for the growth of chloroplasts and seedling survival * Plays a role as a molecular chaperone in plastid differentiation, mediating the creation of internal thylakoid membrane and providing chloroplasts with thermotolerance under heat stress.. |
| 9 | | S2\_4134534 | | 2 | 4134534 | LOC110603286 MANES\_02G052200v8 | Alpha-1,4 glucan phosphorylase L isozyme, chloroplastic/amyloplastic | Largely known for the phosphorolytic degradation of starch. |
| **Starch Content** | | | | | | | | |
| 3 | | S5\_1735523 | | 5 | 1735523 | LOC110614889 MANES\_05G018900v8 | Cytochrome P450 78A9 | * Functions as diverse catalysts and is essential for the production of secondary metabolites, antioxidants, and phytohormones in higher plants. * Plays a key role in the detoxification of xenobiotics. |
| 3 | | S5\_1735523 | | 5 | 1735523 | LOC110614546, MANES\_05G018950v8, LOC110615807 MANES\_05G018800v8 | Uncharacterized membrane protein At1g16860 | * Take part in a variety of physiological processes in plants, such as energy conversion and material transport. * assist in the transfer of various substrates, metabolites, signaling molecules, and phytohormones between cells. * Ion channels in transmembrane proteins move or eliminate ions and harmful chemicals from cells. * serve as enzymes by detecting chemical signals in the surroundings and transmitting them to the interior of the cell |
| 3 | | S5\_1735523 | | 5 | 1735523 | LOC110615808 MANES\_05G018700v8 | Homeobox-leucine zipper protein ATHB-12 | Regulates leaf growth by promoting cell expansion and endoreduplication |
| 6 | | S10\_2319500 | | 10 | 2319500 | LOC110624970, MANES\_10G024000v8, LOC110625096 MANES\_10G024240v8 | PRA1 family protein A3-like | Small transmembrane proteins that operate as VAMP2 and the vacuolar soluble N-ethylmaleimide-sensitive factor attachment receptor protein Rab GTPase receptors to control vesicle trafficking. |
| 6 | | S10\_2319500 | | 10 | 2319500 | LOC110625098 MANES\_10G024300v8 | Receptor-like protein Cf-9 homolog | Primarily as receptor-like proteins or receptor-like kinases, conferring recognition of numerous pathogen compounds and plant hormones, play important roles in plant defense and development. |
| 6 | | S10\_2319500 | | 10 | 2319500 | LOC110624870 MANES\_10G023400v8 | Folylpolyglutamate synthase | By catalyzing the conversion of folates to polyglutamate derivatives, it enables intracellular retention of these cofactors, which are essential substrates for the majority of folate-dependent enzymes involved in one-carbon transfer processes involved in purine, pyrimidine, and amino acid synthesis. |
| 6 | | S2\_1937678 | | 2 | 1937678 | LOC110609737 MANES\_02G021900v8 | Kinesin-like protein KIN-14J | * In charge of conveying a variety of cargos unidirectionally, such as mRNAs, protein complexes, and membrane organelles. * Play important functions in signal transduction, morphogenesis, and mitosis. |
| 6 | | S2\_1937678 | | 2 | 1937678 | LOC110609329 MANES\_02G022100v8 | Serine/threonine-protein kinase BSK7 | Acts as a "central processor unit" (cpu), taking input data from receptors that detect environmental stimuli, phytohormones, and other external events, and converting that data into appropriate outputs, such as changes in metabolism, gene expression, and cell growth and division.. |
| 6 | | S2\_1937678 | | 2 | 1937678 | LOC110610053 MANES\_02G021800v8 | Zinc finger protein CONSTANS-LIKE 2 | * Associated with plant architecture, abiotic stress response, and auxin homeostasis * Involved in flowering time regulation |
| 6 | | S2\_1937678 | | 2 | 1937678 | LOC110609607 MANES\_02G022200v8 | Glutamate--cysteine ligase, chloroplastic | Help in the normal plant development and stress tolerance. |
| 6 | | S2\_1937678 | | 2 | 1937678 | LOC110609453 MANES\_02G021700 | General transcription and DNA repair factor IIH helicase subunit XPB1 | * Initiation transcription of protein- coding gene. * DNA nucleotide repairing. |
| 6 | | S3\_3324735 | | 3 | 3324735 | LOC110610259, MANES\_03G037700v8 | Alpha/beta hydrolase domain-containing protein WAV2 | These enzymes function as esterases, thioesterases, lipases, proteases, dehalogenases, and epoxide hydrolases, catalyzing both primary and specialized (secondary) metabolism.. |
| 6 | | S3\_3324735 | | 3 | 3324735 | LOC110612414 MANES\_03G037600v8 | Protein PLASTID MOVEMENT IMPAIRED 1-RELATED 1 | Plays a crucial part in mesophyll cell movement caused by chloroplast photorelocation mediated by cp-actin. |
| 6 | | S3\_3324735 | | 3 | 3324735 | LOC110612221 MANES\_03G037800v8 | Phospholipid:diacylglycerol acyltransferase 1. | * Good for oil yield increase. * Helps in the growth and development of root, leaf, stem, flower, and seeds. |